JOURNAL
OF THE
FRANKLIN INSTITUTE.
OF THE STATE OF PENNSYLVANIA,
FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXVII. JANUARY, 1884. No. 1.

THE Franklin Institute is not responsible for the statements and opinions advanced by contributors to the JOURNAL.

NOTE ON THE LOSSES PER HORSE-POWER PER HOUR BY CONDENSATION OF THE STEAM IN PIPES AND CYLINDERS OF STEAM ENGINES.

By WILLIAM DENNIS MARKS,
Whitney Professor Dynamical Engineering, University of Pennsylvania.

In this JOURNAL OF THE FRANKLIN INSTITUTE for December, 1883, the writer has published a paper on "The Cheapest Point of Cut-off," in which he has endeavored to show, in a practically useful way, that the greatest economy in the use of steam, and consequently the greatest saving in money, is effected by making the point of cut-off

$$e = \frac{B\left(1 - b\left[1 - \text{nat. log.}\frac{b}{k}\right]\right)}{P_b} + k - b\frac{B}{P_b}\text{nat. log.}\frac{1}{e},$$

within certain limitations as to number of expansions in which

B = the absolute back pressure in lbs. per sq. inch with exhaust open.

P_b = the absolute initial presssure in lbs. per sq. inch.

k = the fraction of the volume of steam cylinder equal to clearance.

b = the fraction of the volume of steam cylinder at which compression begins being measured from the opposite end to e.

What is needed to render this rule practically accurate within the widest range, is to establish the ratio which exists between the steam

furnished by the boiler and that recorded by the indicator diagram, under all the various conditions as to initial and back pressures, and points of cut-off used.

The quantity of steam recorded by the diagram, if deduced by the usual rule is simply the amount of steam remaining as vapor in the steam cylinder after the steam has done its work, and with all its conveyed heat it is immediately thrown away through the exhaust port.

The diagram makes a record of the steam heat converted into work, in foot lbs. Of the steam heat absorbed by the pipes and cylinder walls it makes no record.

It is true, nevertheless, that the usual rule (which is to divide 859375 by the mean effective pressure, multiplied by the specific volume of the steam for the terminal pressure); is of value for the quantity of heat furnished by the boiler being the same, and the condensation being the same, that engine which shows the least rate of steam per horse power per hour has proved most economical, since it has allowed the smallest quantity of steam to pass through the exhaust port unutilized. This quantity may be corrected for compression by inserting the term $1 - \frac{bB}{P_t}$, P_t = absolute terminal pressure.

Another rule deduced by the writer is

$$\text{Weight of steam per HP per hour} = \frac{859375\left(e - b\frac{B}{P_b}\right)}{PS}$$

in which P = the mean effective pressure per sq. inch, and S = the specific volume of the steam for the initial pressure. This rule would give the weight of steam per horse-power per hour actually furnished in the form of vapor, to propel the engine piston, but does not record the steam lost by condensation in pipes and steam cylinder, up to point of cut-off and assumes that the pressure is not lost by throttling up to the actual point of cut-off.

It should be remembered both in the usual rule and our own, that the assumption of an isothermal expansion curve gives, practically, a nearer average of pressures so far as we can judge from the indicator diagram than any other curve, and that in our own rule since the specific volume is taken from the initial pressure, there is no error introduced in the quantity of steam per hour by reason of the terminal

pressure being assumed to vary according to Marriotte's law, thus introducing a large error, because of the great variation in the volume of steam at low terminal pressures.

The very large percentage of the steam furnished by the boiler which is lost through the exhaust in the form of vapor, will be seen from the following examples taken from the report of J. W. Hill, of the competitive tests of three engines at the first Miller's International Exhibition, Cincinnati, 1880.

All of these quantities refer to one HP per hour.

	Condensing Trial.					
	Reynolds Corliss.	Per cent.	Harris Corliss.	Per cent.	Wheelock	Per cent.
	lbs.		lbs.		lbs.	
Actual steam from boilers	20·618		19·364		19·475	
Thermal value per lb	1243·84		1415·86		1301·05	
Total British units of heat	25645·5	100·	25480·3	100·	25340·6	100·
Steam by the usual rule	14·886	72·2	13·755	71·03	13·915	71·45
Thermal value per lb	1179·07		1178·35		1177·9	
Total British units of heat	17152·2	66·9	16206·2	63·61	16390·5	64·62
One HP per hour in heat units	2564·8	10·0	2564·8	10·06	2564·8	10·12
Heat lost by condensation in pipes and cyl. and leakage	5928·5	23·1	6707·3	26·33	6394·3	25·26
Net horse-power	143·19		145·08		143·95	
Ind. horse-power	162·90		165·58		158·38	

	Non-Condensing Trial.					
	Reynolds Corliss.	Per cent.	Harris Corliss.	Per cent.	Wheelock	Per cent.
	lbs.		lbs.		lbs.	
Actual steam from boilers	25.945		23·907		24·928	
Thermal value per lb	1211·30		1255·74		1313·11	
Total British units of heat	31427·2	100·	30022·0	100·	32730·6	100·
Steam by the usual rule	18·896	72·82	18·013	75·35	19·674	75·73
Thermal value per lb	1181·23		1180·89		1181·27	
Total British units of heat	22320·5	71·02	20271·3	67·53	23240·3	71·
One H P per hour in heat units	2564·8	8·16	2564·8	8·54	2564·8	7·84
Heat lost by condensation in pipes and cyl. and leakage	6541·9	20·82	7185·9	23·93	6925·5	21·16
Net horse-power,	121·99		119·74		129·74	
Ind. horse-power	137·02		134·29		139·97	

The value of one HP per hour in heat units has been obtained by dividing 1,980,000 foot lbs. by 772. Other values of the heat unit laying claim to greater accuracy have been obtained, and those having any preference can of course use them.

A fair, comparative test of the skill of engine builders can only be made by assigning as work for each engine a net horse-power proportional to the volume of its cylinder (clearance included), multiplied by its number of strokes per minute.

Each engine should have the same pressure of steam of an equal thermal value. The quantity 2564·8 divided by the quantity of heat furnished to the engine in one hour will then prove the measure of its efficiency both as a means of converting heat into work, and as a machine for the transmission of power.

Corrections can be made for slight variations from the prescribed conditions, but these should be avoided as much as possible.

As a means of comparison any considerable variations from the prescribed conditions will render the experiments valueless. If, however, these conditions are fulfilled, they will enable the comparison to be made between any engines, however much they may differ in mode of construction.

Weighing the water in large tanks is the only safe method. Water meters have rendered much labor of the most painstaking kind quite valueless. This method has the great advantage of doing away with that most unreliable of instruments, the indicator, and substituting for it scales and thermometers.

Scales can be obtained of any desired degree of accuracy, as can also thermometers, by applying to the authorities at the Johns Hopkins University, Baltimore, Md., or to Yale College, New Haven, Conn.

The indicator will then be relegated to its proper place as a means of detecting gross errors of construction, and of determining average means of effective, initial and terminal pressures with relative accuracy.

It is worthy of note that the proportion of weight of actual steam to the weight of steam by the usual rule per HP per hour, does not represent the proportion of the heat furnished to the heat lost through the exhaust, since the thermal value of the steam at the terminal pressure is less than its value at initial pressure.

This can be seen from the table which shows the percentages of the

weights of water to be greater than the percentages of the heat units at boiler and terminal pressures.

The most suggestive point of the table is the approximate uniformity of the ratio of water by the indicator to the actual water evaporated for both condensing and non-condensing engines per HP per hour, its variation is within the limits of error of the best indicators.

If this ratio prove constant then will the discussion of the cheapest point of cut off, which has proved itself true within the range of Mr. Hill's experiments hold good for all conditions, but this point remains to be verified by experiment, as already set forth in a previous paper.

THE CHEAPEST POINT OF CUT-OFF.

By De Volson Wood.

It is proper to observe, that in Professor Marks analysis of this problem in the last December number of this Journal, the constant charges are assumed to be a constant fraction of the cost of steam. This, in other words, is equivalent to assuming that the constant charges *vary* with the cost of steam, a proposition involving, in general, a self-contradiction. But granting that, in the special case considered by Professor Marks, which involves a given horse-power per hour, is correctly represented by his equation (5), the result will be, independent of constant charges, but *not so for any other law.* The solution then is not general but *special;* and we may draw the inference that "the point of cheapest cut-off" is *generally* dependent upon the constant charges.

Artificial Auroras —Prof. Lenstrom, director of the Meteorological Observatory of Sodankygla, Finland, produced artificial auroras by passing a strong electric current through a copper wire, which surrounded the hill of Pïetrotneturi, near Cullala. A few days afterwards he surrounded, in like manner, a space of 900 square metres on the summit of the hill Ovatnaturi. In the latter experiment he saw the cone surrounded by a yellowish light, which resembled the streamers of the aurora borealis.—*Les Mondes,* April 21, 1883. C.

THE THEORY OF TURBINES.

[ABSTRACT.]

By ROBERT H. THURSTON.

[Am. Soc. Mechanical Engineers: November Meeting, New York, 1883.]

(Concluded from page 459.)

24. Centrifugal action and friction modify the theory of the turbine, as already indicated; the one altering, in equal amount, both the energy expended and the energy usefully applied, and the other by reducing the head, reaching and impelling the wheel. It has been seen that these quantities of work can be represented by expressions involving the velocities of current and quantities having the forms $f(n) = N$ and $f(f) = F$, in which n is the value of $\frac{r_2}{r_1}$ and f is a function of the coefficient of fluid friction. Values of N have been given in Tables I–IV, for various values of h_c, the head due centrifugal action, and those of $f(f)$ are easily calculated when the elements and action of the wheel are given.

The expressions for head and efficiency then become, for the first form of wheel, friction included.

$$h_1 - h_2 = \frac{n^2+1}{2g}(2\,ar_1v_1 - a^2r_1^2) - Nv_1^2 \tag{62}$$

$$h_1 = \frac{1}{2g}(n^2v_1^2\sec.^2\beta + 2ar_1v_1 - a^2r_1^2 - Nv_1^2 + Fv_1^2) \tag{63}$$

$$E = \frac{(n^2+1)(2arv_1 - a^2r_1^2) - Nv_1^2}{n^2v_1^2\sec.^2\beta + 2arv_1 - a^2r_1^2 - Nv_1^2 + Fv_1^2}. \tag{64}$$

When $v_1 = ar_1$; $v_2 = nar_1 = nv_1$,

$$E = \frac{n^2+1-N}{n^2\sec.^2\beta + 1 - N + F}; \tag{65}$$

when $n = 1$,

$$E = \frac{2-N}{\sec.^2\beta + 1 - N + F}; \tag{66}$$

and when $\beta = o$,

$$E = \frac{n^2+1-N}{n^2+1-N+F}, \tag{67}$$

which becomes unity when F becomes o.

The magnitude of the quantity N which appears in the completed equations for efficiency and head may now be readily determined for the cases studied. It is not, as is easily shown, the value of $f(n)$,

which is obtained by considering only the absolute whirl, and as deduced in article 3.

Since the motion of the water in space is the resultant of the motion of the current relatively to the wheel and the motion of the wheel itself, it is evident that the path in space being given, the motion of the water at each point in that path may be decomposed into two components, the one coincident with the wheel, and the other the motion relative to the wheel and along the bucket channels. These two motions may be studied separately and their joint effect ascertained by combining the effects of their separate action.

The head driving the wheel being reduced by friction, the speed of wheel, $w_2 = v_2 = ar_2$, is correspondingly decreased. The value of v_2 is that due to the head.

$$H = (n^2v_1^2 \sec.^2\beta + 2arv_1 - a^2r_1^2 - Nv_1^2 + Fv_1^2) \div 2g,$$

minus, the last term, *i. e.*, to

$$h_1 = H - h_f = (n^2v_1^2 \sec.^2\beta + 2ar_1v_1 - a^2r_1^2 - Nv_1^2) \div 2g,$$

and the speed of wheel must be adjusted to this last value of h. Friction produces a retardation of flow throughout the whole column of fluid.

25. It thus remains to determine the value of the factor, $Nv_1^2 = 2gh_e$, which enters all final equations. It is evident that it cannot be that value of $2gh_e$ found in the introduction as a measure of *total* centrifugal action, since only the motion of the water relative to the wheel is considered, when measuring the energy gained or lost relatively to the bucket. It must be some other value greater or less. The steadying effect, however, is approximately measured by the variation of the total centrifugal action for which values of $f(n)$ have been given, and these values are determined largely by the form of bucket. Variation of speed does not alter the path on the wheel, although it does vary velocity in that path.

As the difference of head on the entrance and exit sides of the wheel is due to the combined action of the two components of the absolute motion of the water, we obtain, for the difference of head due one, a maximum

$$h_e'' - h_e' = \frac{Na^2r_1^2}{2g} = \frac{(n^2 - 1)\,a^2r_1^2}{2g}, \tag{68}$$

and for that due the relative motion on the wheel, according to the theorem of Bernouilli,

$$h_r' - h_r'' = \frac{V''^2 - V'^2}{2g}. \tag{69}$$

The net difference of head is then,

$$h_p - h_2 = h_o'' - h_o' - h_r' + h_r'' = [V'^2 - V''^2 + (n^2 - 1)a^2r_1^2] \div 2g. \quad (70)$$

When the total difference of head is zero,

$$V''^2 = V'^2 + (n^2 - 1)ar_1^2; \quad V'^2 = V''^2 - (n^2 - 1)a^2r_1^2, \quad (71)$$

and the head due the relative velocity of exit from the wheel must be equal to the sum of the heads due initial relative velocity of current and centrifugal action.

When the difference of head due change of relative motion is zero, and no acceleration occurs in the bucket from that cause,

$$V''^2 - V'^2 = o; \quad h_p - h_2 = (n^2 - 1)\frac{a^2r_1^2}{2g};$$

and the total difference of head is that due maximum centrifugal action.

But, in the analysis which has been given, only the relative motion on the wheel has been taken into account. That component which coincides with the motion of the wheel must, in turbines having wide crowns, be considered, and its effect in producing change of head in the wheel must be determined. This change of head is that due centrifugal force and, as this component of the motion of the water coincides with that of the wheel, the effect of centrifugal action, so far as it is due to this component, must be that obtained in Case I, and when $v_1 = a\,r_1$, we shall have for its measure

$$N = f(n) = n^2 - 1 \quad (72)$$

the values of which expression are given in Table I.

Introducing this value of N into the equations for efficiency and head, for the case of the turbine of uniform direct flow, they become

$$E_{max.} = \frac{n^2 + 1 - N}{n^2 \sec^2.\beta + 1 - N} = \frac{2}{n^2 \tan.^2\beta + 2} \quad (73)$$

$$2gh = n^2 v_1^2 \sec.^2\beta - Nv_1^2 = (n^2 \tan.^2\beta + 2)\,v_1^2 \quad (74)$$

which, when $\beta = o$, give $E_{max.} = 1$ as before, and $h = \frac{v_1^2}{g}$ *i. e.*, h_1 is twice the height due the whirl v_1, which condition is essential to maximum possible efficiency.

When the form of the bucket-channel is changed the total centrifugal action is altered, but the difference of head due the relative velocity of the current is also changed and since, in all cases, the total difference of head at the entrance and exit sides is the sum of the head due the maximum possible amount of centrifugal action and that due

the change of relative motion within the wheel, it becomes evident that a difference of form such as distinguishes the Whitelaw wheel from the Barker mill, the velocity of exit remaining unchanged, simply alters the method of variation of pressure within the passages of the wheel without affecting its efficiency, or its best speed, however the total centrifugal action may be modified by such changes of absolute velocity of whirl within them. The values of $f(n)$ given above in Tables II–IV for total centrifugal action corresponding to various methods of actual variation of whirl are, therefore, not of importance in the theory of the turbine, so far as the treatment here adopted is concerned. They relate to the motion of the water in space, and when that path is rectilinear, and when the total head due centrifugal force is zero, the quantity $Nar^2 = (n^2 - 1)\ a^2r^2$ will, nevertheless, appear in the analysis. With wheels having narrow crowns, both this and the total centrifugal action may be neglected.

25. The Segner or Barker wheel illustrates the maximum effect of centrifugal force. In its rudest form the total centrifugal action is a maximum, the relative velocity of the water in the wheel does not change, and neglecting friction, when $v_2 = w_2 = ar_2$, $h_c = \frac{a r_2^2}{2g}$;

$$E = \frac{1 - N}{\sec.^2 \beta - N}$$

which becomes $E = 1$, when $\beta = 0$.

But $v_2 = \infty$, since, for $E = 1$, we must have

$$v_2^2 = 2gh_1 + a^2r_2^2;\ v_2 = ar_2$$

and this is only possible when the quantity $2gh_1$ becomes indefinitely small in comparison with $a^2 r_2^2$.

It then follows that the head, h_2, at exit is

$$h_2 = h_1 + \frac{a^2r_2^2}{2g} \tag{75}$$

$$v_2 = \sqrt{2gh_2} = \sqrt{(2gh_1 + a^2r_2^2)}. \tag{76}$$

The energy due this velocity is

$$U_1 = \frac{DQ}{2g}(2gh_1 + a^2r_2^2). \tag{77}$$

The absolute velocity of exit, V_2, is, otherwise,

$$V_2 = v_2 - ar_2 = \sqrt{(2gh_1 + a^2r_2^2)} - ar_1\ ; \tag{78}$$

and the energy wasted is

$$U_2 = \frac{V_2^2}{2g} = \frac{DQ}{2g}\left(\sqrt{2gh_1 + a^2 r_2^2} - ar_2\right)^2 \qquad (79)$$

The energy utilized is then

$$U = U_1 - U_2 = \frac{DQ}{2g}\left[(2gh_1 + a^2r_2^2) - \left(\sqrt{2gh_1 + a^2r_2^2} - a\,r_2\right)^2\right]$$

$$= \frac{DQ}{2g}\left(2\,a\,r_2\sqrt{2gh_1 + a^2r_2^2} - a^2r_2^2\right) \qquad (80)$$

which approximates to DQh_1 as ar_2 approaches infinity; for developing $\sqrt{2gh_1 + a^2r_2^2}$, by the binomial formula,

$$U = \frac{DQ}{g}.\ ar_2\left(\frac{gh_1}{ar_2} - \frac{g^2h_1^2}{2a^3r_2^3} + \text{etc.}\right);$$

which gives, when $ar_2 = \infty$,

$$U = DQh_1.$$

The efficiency is

$$E = \frac{U}{U_1} = \frac{2a\,r_2\sqrt{2gh_1 + a^2r_2^2} - a^2r_2^2}{2gh_1 + a^2r_2^2}; \qquad (81)$$

and, taking $Z' = \dfrac{ar_2}{\sqrt{2gh_1}}$,

$$E = \frac{2z'\sqrt{1 + z'^2} - z'^2}{2 + z'^2}, \qquad (82)$$

which increases toward unity, as a limit, as z' increases, without limit.

If centrifugal action could be neglected, taking the initial velocity and its proportion of the head V_1, and $\dfrac{V_1^2}{2g}$, as zero, the pressure head is $h_p = h_1$ and by Bernouilli's Theorem, since

$$h_1 = 0 + h_p \text{ and } 0 = 2g\,(h_1 - h_p),$$

the relative velocity of exit, V'', is such that

$$V''^2 = 2gh_1.$$

26. The distribution of energy in the turbine is easily determined in the special cases already studied. It may be traced, in a still more general and complete manner, by obtaining a measure of the velocity, absolute and relative, step by step, as the water passes through the turbine, without reference to the proportions of the wheel and without prescribing the method of flow.

Certain fixed relations always exist between the angles and the velocities of wheel and of water which may be easily determined.

Since the volume of flow is the same, wherever measured,

$$Q = 2\pi r_1 d_1 V_1 \sin.\ a = 2\pi r_2 d_2 V'' \sin.\ \beta;$$

$$\frac{\sin.a}{\sin.\beta} = \frac{n d_2 V''}{d_1 V_1} \tag{83}$$

When the velocities, V_1 and V'', are decomposed into radial flow, u_1 and u_2, and whirl, v_1, v'',

$$\tan.\ a = \frac{u_1}{v_1};\ \tan.\ \beta = \frac{u_2}{v''} \tag{84}$$

$$\tan.\ a = \frac{u_1}{V_1 \cos.\ a};\ \tan.\ \delta = \frac{u_1}{V_1 \cos.\ a - w_1} \tag{85}$$

which becomes $\tan.\ \delta = \tan.\ a$ when $w_1 = 0$, and $\delta = 90°$ when $w_1 = V_1 \cos.\ a$. a becomes greater than a right angle when $w_1 > V_1 \cos.\ a$.

Also,

$$V_1 \sin.\ a = V^1 \sin.\ \delta;\ V_1 \cos.\ a - V' \cos.\ \delta = w_1,$$

$$\frac{V'}{V_1} = \frac{\sin.\ a}{\sin.\ \delta};\ V_1 = \frac{V^1 \sin.\ \delta}{\sin.\ a};\ V' = \frac{V_1 \sin.\ \delta}{\sin.\ a};$$

$$\frac{V_1}{w_1} = \frac{\sin.\ \delta}{\sin.\ \delta \cos.\ a - \sin.\ a \cos.\ \delta} = \frac{\sin.\ \delta}{\sin.\ (\delta - a)} \tag{86}$$

and the ratio of the areas of sections is

$$\frac{O_2}{O_1} = \frac{V_1}{n w_1} = \frac{\sin.\ \delta}{n \sin.\ (\delta - a)} \tag{87}$$

To avoid disturbance at the entrances to the wheel-passages, the line of the tangent to the entrance side of the bucket must be coincident with that of the relative motion of the current entering the wheel; *i. e.*,

$$(V_1 \cos.\ a - w_1) : V_1 \sin.\ a = 1 : \tan.\ \delta;\ \tan.\ \delta = \frac{V_1 \sin.\ a}{V_1 \cos.\ a - w_1} \tag{88}$$

In all cases, also,

$$\tan.\ a = n^2 \frac{w_1 d_2}{v_1 d_1} \tan.\ \beta \tag{89}$$

The velocity, V_1, of the water leaving the guides is due to the dif-

ference of pressure caused by the difference of head within and without these orifices. The total head, H, is reduced by friction to

$$h_1 = H - h_f;$$

The difference of head at entrance to, and exit from, the guides is $h_1 - h_p$ and the velocity of exit is

$$V_1 = \sqrt{[2g\,(h_1 - h_p)]} = \sqrt{[2g\,(H - h_f - h_p)} \qquad (90)$$

and its energy is $DQ = \dfrac{V_1}{2g}$ (91)

Or, h_p being unknown and V_1 given,

$$h_p = h_1 - \frac{V_1^2}{2g} \qquad (92)$$

The relative velocity of entrance into the wheel, V', is such that the relative energy is there

$$DQ\frac{V'^2}{2g} = \frac{DQ}{2g}\,(V_1^2 + w_1^2 - 2V_1 w_1 \cos.\, a) \qquad (93)$$

The stream enters the bucket-channels with the velocity V' and with the above energy. This relative velocity and this energy are retained in the buckets, friction being here neglected, except as they are modified by centrifugal action, which increases the velocity in outward-flow wheels, and decreases it in inward-flow turbines.

The final relative velocity becomes V'' at the discharge side of the wheel, and the relative energy is there

$$\frac{DQ}{2g}\ V''^2 = \frac{DQ}{2g}\left(h_p - h_2 + \frac{V'^2}{2g} + 2gh_c\right)$$

$$= DQ\left[(h_1 - h_2) + \frac{w_1^2 - 2V_1 w_1 \cos.\, a + 2gh_c}{2g}\right] \qquad (94)$$

But,

$$V_1 = \frac{V''O_2}{O_1};\ \text{and}\ w_2 = nw_1$$

$$\therefore\ V''^2 = 2g\,(h_1 - h_2) + w_1^2 - 2\frac{O_2}{O_1}\,w_1 V''\cos.\, a + 2gh_c$$

$$V'' = \sqrt{\left[2g(h_1 - h_2) + \frac{O_2^2}{O_1^2}\,w_1^2\cos.^2 a + 2gh_c\right]} - \frac{O_2}{O_1}\,w_1\cos.\, a \qquad (95)$$

It is impossible, in these turbines, to make $\beta = 0$, as this angle must be large enough to permit free discharge of the volume of flow, Q, without high velocity, u_2, of direct flow; it must always be so large that

$$\tan. \beta = \frac{u_2}{w_2} \tag{96}$$

But this value is usually small enough to permit the common assumption that $V'' = w_2$; and as $\frac{w_2}{w_1} = \frac{r_2}{r_1} = n$; $\frac{w_1}{r_1} = \frac{w_2}{r_2}$;

$$V''^2 = 2g\,(h_1 - h_2) + n^{-2}V''^2 - 2\,V''^2 \cos.\, a\, \frac{O_2}{nO_1} + 2gh_e;$$

$$w_2 = V'' = \sqrt{\frac{2g\,(h_1 - h_2) + 2gh_e}{1 + 2\,\frac{O_2}{nO_1} \cos.\, a - n^{-2}}} \tag{97}$$

Neglecting centrifugal action, and making $a = 90$, we should have for turbines without guide-curves, were the case possible,

$$w_2 = V'' = \sqrt{2gh_1}$$

as before, when β, w_1, r_1, and h_2 become 0 and $n = a$.

When the head is so equally divided that we may make

$$h_1 - h_2 = h_2 + h_e \text{ and } V_1 = V''; \; w_1 = V_1;$$

$$h_1 = 2h_2 + h_e;$$

we obtain

$$V''^2 = V_1^2 = 2g\,(h_1 - h_2) + w_1^2 - 2\,V_1 w_1 \cos.\, a + 2gh_e$$

$$= \frac{2g\,(h_1 - h_2) + 2gh_e}{2 \cos.\, a} \tag{98}$$

which, when $n = 1$, $h_2 = 0$, and $h_e = 0$, becomes

$$V_1^2 = \frac{2gh_1}{2 \cos.\, a} \tag{99}$$

The absolute velocity of exit, V_2, is the resultant of the motion of wheel and of the discharged current.

$$V_2^2 = V''^2 + w_2^2 - 2\,V'' w_2 \cos.\, \beta \tag{100}$$

and the energy thus lost is

$$U_2 = DQ\,\frac{V_2^2}{2g} \tag{101}$$

which approaches zero as the values

$$\beta = 0,\ V'' = w_2$$

are approached.

The value of w_2 may be obtained in terms of the angles α and δ; thus

$$w_2 = \sqrt{\frac{2g\,(h_1 - h_2) + 2gh_e}{1 + 2\,\frac{\cos.\,\alpha\,\sin.\,\delta}{n^2\,\sin.\,(\delta - \alpha)} - n^{-2}}} \tag{102}$$

$$w_1 = \frac{w_2}{n} = \sqrt{\frac{2g\,(h_1 - h_2) - 2gh_e}{n^2 + 2\,\frac{\cos.\,\alpha\,\sin\,\delta}{\sin.\,(\delta - \alpha)} - 1}} \tag{103}$$

For the value of the head, h_p, we have

$$h_p = h_1 - \frac{V_1^2}{2g} = h_1 - \frac{w_1^2}{2g}\cdot\frac{\sin.^2\,\delta}{\sin.^2\,(\delta - \alpha)};\ = h_1 - \frac{(h_1 - h_2 - h_e)\,\sin.^2\,\delta}{n^2\,\sin.^2\,(\delta - \alpha) + 2\cos.\,\alpha\,\sin.\,\delta - \sin.\,(\delta - \alpha) - \sin.^2\,(\delta - \alpha)} \tag{104}$$

For the parallel-flow wheel, in which $n = 1$, $N = 0$, when $w_2 = V''$,

$$w_2 = \frac{g\,(h_1 - h_2)}{V_1\cos.\,\alpha}$$

an equation used by Vallet in designing.

The velocity V, due to the whole effective head, is

$$V = \sqrt{2g\,(h_1 - h_2)}$$

and, hence,

$$2w_2 V_1\cos.\,\alpha = V^2;\ w_2 = \frac{V^2}{2\,V_1\cos.\,\alpha} \tag{105}$$

The useful head is

$$h_e = h_1 - \frac{V_2^2}{2g} \tag{106}$$

and the efficiency is

$$E = \frac{h_e}{h_1} = \frac{h_1 - \frac{V_2^2}{2g}}{h_1} = 1 - \frac{V_2^2}{2gh_1}$$

$$= 1 - \frac{d_1}{d_2}\,\frac{\tan.\,\alpha}{\tan.\,\beta}(1 - \cos.\,\beta) \tag{107}$$

The value of the work of centrifugal action, DQh_c, in all these equations is, as in the preceding cases, not the *total* work of absolute motion but the work due to that component which is coincident with the wheel and $h_c = (n^2 - 1)\, a^2 r_1^2$. But since, in the general case, the relations of whirl, of wheel, and of water are not fixed, the equation cannot be simplified as in the case of the turbine of uniform radial flow.

27. The form of curves for guides and buckets is evidently not prescribed by the general theory of the turbine. The angles, α, β and δ, the proportions of the wheel, its principal dimensions, and the cross sections of the passages, are determinable, and the values obtained are usually consistent with a wide variety of forms of curves. In many cases, also, the curve may be very considerably modified, to suit the ideas of the designer, by slightly altering the diameters and depths of the wheel. Thus, an increase of depth at the outer periphery reduces the velocity of direct flow and causes a corresponding change in the form of bucket, permitting a smaller value of the exit angle, β, than can be obtained with uniform direct flow, if the volume of water discharged be constant. Since the force exerted on the passing stream by the bucket or the guide is simply a deviating force, and since the angles of entrance and exit, only, are fixed by the theory of the wheel, it is obvious that the designer may, within certain limits, choose the form of the curve, to suit himself, or to meet any specified conditions.

The best form of curves is that which causes least loss of energy, and at the same time produces such total centrifugal action, if any, as may be best for the kind of wheel to be constructed, *i. e.*, that which gives minimum centrifugal action in outward and maximum in inward flow wheels. The losses of energy are due to friction and malguidance, and both these wastes are least on curves of smallest curvature. Centrifugal action is usually a maximum on curves of small curvature, and on those which deviate least at the terminal end, while it is zero when the path of the water in space is a straight line, since its magnitude is determined entirely by the path in space, and not simply by the path on the wheel.

The curve may be "laid down" very readily by plotting the desired path in space on a full-size drawing of the wheel, and from it determining the path on the wheel. Or it may be obtained by tabulating a series of differences of absolute and relative velocities of the water and of velocities of wheel, and laying down the curve, step by step, as

the resultant of the motions of water and wheel. Or the path may be plotted directly from the equation of the curve.

28. The equations of these curves, in space and on the wheel, are readily derived thus:

The elementary angle, $d\gamma$, traversed on the wheel is the difference between the angles, $d\varphi$ and $d\theta$, traversed by the wheel and by the water. Then

$$d\gamma = d\varphi - d\theta \tag{108}$$

The angle moved through by the wheel is always directly proportional to the time, since the rotation of the wheel is uniform, and

$$d\varphi = c dt \tag{109}$$

The motions of the water, both in whirl and in direct flow, are determined by the designer. In illustration, take two common cases:

(1.) Let the path of the water in space be rectilinear and the retardation uniform, as in some turbines having narrow crowns.

The equation of the path is then

$$\Delta s = (r - r_1) \operatorname{cosec.} \alpha \tag{110}$$

and, since retardation is uniform,

$$\frac{d^2s}{dt^2} = -f \tag{111}$$

Then

$$d\varphi = c dt;\ ds = V_1 dt - f t dt \tag{112}$$

$$r - r_1 = \sin.\ \alpha \left(V_1 \frac{\varphi}{c} - \tfrac{1}{2} f \frac{\varphi^2}{c^2} \right) \tag{113}$$

and, for any value of φ,

$$\varphi_m = c \sqrt{\left(\frac{(r_m - r_1)^2}{\sin.^2 \alpha} + \frac{V_1^2}{c^2 f^2} \right)} - \frac{V_1}{f} \tag{114}$$

The values of the constants are easily determined. V_1 is the velocity of exit from the guide-curves, and is obtained from the equation

$$V_1 = \frac{u_1}{\operatorname{cosec.} \alpha} \tag{115}$$

The value of c is known when the speed of the wheel is given and f is fixed by the value of V_1, thus:

$$s_1 = \frac{V_1^2}{2f};\ s_2 = \frac{V_2^2}{2f} = \frac{u_2^2 \operatorname{cosec.}^2 \beta}{2f};$$

$$s - s_1 = (r_2 - r_1)\operatorname{cosec.}\beta = \frac{V_2^2 - V_1^2}{2f} = \frac{u_2^2 \operatorname{cosec.}^2\beta - V_1^2}{2f};$$

$$f = \frac{u_2^2 \operatorname{cosec.}^2\beta - V_1^2}{2(s_2 - s_1)} \tag{116}$$

making $u_2 = bu_1$,

$$f = V_1^2(b^2 \operatorname{cosec.}^2 a - 1) \div 2(s_2 - s_1) = \frac{V_1 \sin. a}{2(r - r_1)}(b^2 \operatorname{cosec.}^2 a - 1) \tag{117}$$

Common values are $V_1 = 0{\cdot}7\ \sqrt{2gh_1}$; $u_1 = u_2 = 0{\cdot}2\sqrt{2gh_1}$; $b = 1$; $a = 20°$.

In the above case, no centrifugal action occurs.

(2.) Let the direct flow be uniform and the whirl uniformly retarded as in the turbines of Vallet.

We have, for the path in space, $rd\varphi = edt$; $dr = edt$; $dv = d.\frac{r_2 - r}{r_2 - r_1}v_1$; $rd\theta = vdt$.

When the path has been extended from r_1 to mr_1, since $\frac{r_2}{r_1} = n$,

$$\theta_m = \frac{v_1}{e(n-1)r_1}\int_{r_1}^{mr_1}(nr_1 - r)\frac{dr}{r};$$

$$= \frac{v_1}{e(n-1)}(n \log_e m - m + 1) \tag{118}$$

When $m = n$,

$$\theta n = \frac{v_1}{e(n-1)}(n \log_e n - n + 1) \tag{119}$$

The values of θn locate the position of the terminal of the curve.

For the path on the wheel and the form of bucket,

$$\varphi = \frac{w_2}{r_2} = \frac{w_1}{r_1};\ dr = edt;\ rd\theta = vdt;$$

$$rd\varphi = \frac{w_1}{r_1}rdt;\ d\gamma = d\varphi - d\theta;\ v = \frac{r_2 - r}{r_2 - r_1}v_1;$$

$$d\gamma = \left(\frac{w_1}{r_1} - \frac{v}{r}\right)dt;$$

$$= \left(\frac{w_1}{er_1} - \frac{nr_1 - r}{e(n-1)r_1 r}v_1\right)dr \tag{120}$$

$$\gamma_m = \int_{r_1}^{mr} \left(\frac{w_1}{er_1} - \frac{nr_1 - r}{e(n-1)r_1} \right) \frac{dr}{r};$$

$$= \frac{w_1}{e}(m-1) - \frac{v_1}{e(n-1)}(n \log_e m + m - 1) \qquad (121)$$

and when $m = n$,

$$\gamma_n = \frac{w_1}{e}(n-1) - \frac{v_1}{e(n-1)}(n \log_e n + n - 1) \qquad (122)$$

which are the equations of the bucket curve and path of the water on the wheel. Making $w_1 = o$, we have $\gamma_m = -\theta_m$.

When $w_1 = v_1$, as in the turbine of uniform direct flow of which the theory has been given,

$$\gamma_m = \frac{v_1}{e}\left(m - 1 - \frac{n \log_e m}{n-1} - \frac{m-1}{n-1}\right) \qquad (123)$$

$$\gamma_n = \frac{v_1}{e}\left(n - \frac{n \log_e n}{n-1} - 2\right) \qquad (124)$$

Equations may be similarly derived for any practicable method of flow which the engineer may desire to secure. It will, however, be sometimes found impracticable to adopt certain forms of bucket with certain proportions of wheel, and only careful study will determine the best arrangement.

29. "Centrifugal" pumps, which are to be considered as reversed turbines, and in which centrifugal action may or may not greatly modify the relative motion of the water passing through their channels, are subject to the same laws, and the common theory of their action is to be modified in a similar manner. The remarks above made, in regard to forms of bucket and methods of determining their curves, also apply to this class of machines and the methods to be pursued in securing minimum wastes of energy are the same as for turbines. There is, however, one important difference to be noted between the turbine and the pump, viz., the heads due their action differ by the quantity $2h_f$, since friction opposes motion either toward or from the machine. For the turbine, $h_1 = H - h_f$; for the pump, $h_1 = H + h_f$, the head reaching and driving the turbine differing from that sustained by the pump by the quantity

$$H + h_f - (H - h_f) = 2h_f.$$

NOTE:—In the debate which followed the reading of the above paper, the author stated that he, when developing the expressions for

"total" centrifugal force presented at the opening of the paper, expected that they would find a place in the equations forming the theory of the wheel, but that as seen later in the paper, they are not so applicable. The equations remain as in the accepted theory, which is correct in form, although he believes that it will prove necessary to revise the nomenclature somewhat. The so-called "centrifugal" action is hardly that which is so understood popularly. He shows that the spiral of the Whitelaw Wheel does not permit the removal of the expression for so-called centrifugal force from its equation as its inventor thought (See J. F. I., for September); that Wheel and the Barker Mill have the same theory.

Hoboken, July, 1883.

Jules Duboscq.—Duboscq has been honored with two gold medals by the Société d'Encouragement. The first was granted in 1855, for his electric regulator, the second in 1857, for his improvements in the stereoscope, which contributed to the great and rapid popularity of that wonderful invention of Wheatstone and Brewster. He has since continued to devote his attention to the development of optics, and he is now considered everywhere as the master of experimental art in all branches of that interesting science. The introduction of the electric regulator into the projecting lantern was of immense value; his subsequent improvements in the oxyhydrogen lamp made the projecting lantern applicable to all varieties of experiment. At the exposition of 1855, Duboscq showed, for the first time, the projection of magnified photographs of microscopic objects, which gave images upon the screen similar to those of the solar microscope. By an ingenious combination he also obtained the effect of the polyorama, with a single luminous source, and projected upon the images of microscopic objects that of a micrometer which showed the true magnitude. His inventions for presenting the images in their natural positions, for projecting objects in a horizontal as well as in a vertical plane, for exhibiting all the phenomena of polarization, for showing spectra in relief and the various forms of turning spectra, are but a few of the results for which the scientific world is indebted to his ingenuity. His assistance has also been very useful to many other experimenters in their researches. Especial mention may be made of the practical success which he gave to Jellett's saccharimeter, and to Bertin's acknowledgement of his valuable assistance in the study of magic mirrors.—*Bul. de la Soc. d'Encour.*, Feb. 1883. C.

WATER-LINE DEFENCE AND GUN-SHIELDS FOR CRUISERS.

By N. B. CLARK, Passed Assistant Engineer, U. S. N.

[From the Proceedings of the U. S. Naval Institute; revised and considerably enlarged by the author for publication in the JOURNAL.*]

"An examination of facts is the foundation of science."

A well designed war-ship may be termed an aggregation of compromises. The augmentation or extension of any quality beyond a certain limit can only be made at the expense and by the curtailment of some other requisite, equally, or perhaps more, desirable.

Everything has weight, and to carry weight requires displacement, which involves increased resistance and greater engine power. The distribution of weights so as to produce the best general results is a problem of the greatest importance, for upon it depends the success or failure of the vessel, as measured by the standard of comparison with others.

The cardinal requisites of a war-ship, mentioned in the order of their importance, are:

1st. Defensive power—ability to keep the ship afloat, and the crew alive.

2d. Offensive power—ability to destroy or disable an enemy's ships and men.

3d. Mobility—power to chase down or ram an enemy.

4th. Quarters—giving healthful and sanitary accommodations to officers and men, necessarily conducive to proper morale and discipline.

Of these prime requisites, defence of the water-line is, to a war-ship, a matter of paramount importance; for even though a vessel had the speed of the wind, was armed with the most powerful guns, commanded by the most capable officers, and manned by the bravest crew, all would avail nothing if she could not be kept afloat in combat.

The great improvements attained in the rapidity of manipulation,

* No. 25, Proceedings U. S. Naval Institute, "The Development of Armor for Naval Use," by Lieutenant E. W. Very, U. S. N., a member of the Naval Advisory Board, having been published after this paper, in its original form, was read before the Washington Branch (June 7, 1883), has necessitated some revision and additions by the author, to correct certain statements by Lieutenant Very in relation to the curved shield, which are herein claimed to be erroneous.

accuracy of fire and range of the modern breech-loading rifle guns, make the defence of the water-line a matter for the most serious consideration. Percussion shells of large size, each one of which is in itself a mine, will render an efficient defence of the water-line a problem very difficult of solution. But even if absolute protection cannot be attained, the importance of the matter demands the adoption of every available expedient that may lessen the chances of fatal disaster and ensure the flotation of the ship—1st, by keeping the water out, as far as possible; 2d, by freeing the vessel of water, should it unfortunately gain entrance.

A water-line defence, consisting of armor disposed vertically, is at the mercy of *elongated* shot, concentrating their energy on the small area of their cross sections; and if such armor extends the length of the vessel, the narrow bow and stern are encumbered with a weight entirely disproportioned to their flotative power.

Vertical side armor does not give an efficient protection, unless supplemented by deck-plating; but if the aggregate weight of the vertical armor and deck-plating is distributed over the vessel in the form of a curved shield, having a cross section conforming to the arc of a circle, extending across from side to side, and so placed within the ship as to have its crown slightly above the water-line, with the sides attached to the vessel some four feet below it at ordinary load draught, a much greater measure of protection can thereby be obtained with the same weight of armor; as elongated shot strike it upon their sides, thereby presenting the much greater area of their longitudinal sections, by which they would be deprived of much of their penetrating power. Moreover, the glancing effect of a curved shield will enable a comparatively light plate to throw off a heavy shot.

Immense energy is stored in a projectile by propelling it by as great a pressure of an elastic gas as the gun will safely bear without rupture, from the breech to the muzzle thereof; this energy is accumulated from transverse strains on successive sections of the length of the bore, transformed into longitudinal motion. As the energy is acquired during the time of the passage of the shot from the breech to the muzzle of the gun the time element is an important factor.

When a shot strikes armor at right angles to its surface, this enormous energy, gradually acquired, is sought to be resisted during the infinitesimal time the shot at its immense velocity is passing the almost inappreciable distance the armor will stretch before breaking; con-

sequently projectiles can be made to penetrate a thickness of armor much greater than the sides of the gun from which they were fired. By disposing plates at an acute angle to the line of fire, a much greater time element is given to the armor which will enable it to resist the energy of the projectile.

In order to obtain the best result with deflecting armor it must have a hard surface, and the plate should have sufficient rigidity to turn the end of the projectile. If the plate is soft, so as to permit the shot to bite, or if it does not possess sufficient rigidity to turn the end of the projectile before it obtains a facing, it may go through.

When a projectile strikes a deflecting surface sufficiently hard and rigid to deflect it, the angle of deflection is about equal to the angle of incidence and its action is, therefore, analogous to the reflection of light, when impinging on a bright surface. When the projectile force is far in excess of the resistance of an inclined plate, the shot in going through turns in a direction normal to the surface of the plate, its action being analogous to the refraction of light—when passing through a transparent medium—and for the same reason, as it moves in the direction of the least resistance, there being a less thickness of plating in a direction normal to the surface, than in an oblique direction.

When a projectile of high velocity impinges upon an acute deflecting surface, it receives so severe a drubbing from the area of the plating acted on, being largely in excess of its own surface, that the shot is usually broken up, even by very light plating.

The principle of deflection as a means of defence is by no means new, as it was applied in the shields of the soldiers of ancient Rome, and is applied in those of many uncivilized tribes of the present day.

The application of the principle of deflection for the protection of war-ships dates back to the beginning of the present century, a United States patent having been granted for such a design as early as 1804.

The Confederate government, during the late war, constructed all their armored vessels upon the deflective principle; and the vessels then built proved remarkably successful, when the great difficulties under which they were constructed are taken into consideration; but the angles of incidence presented were entirely too great to obtain the best results.

If the angles of incidence are reduced, the protected space within is correspondingly contracted, so that it is doubtful if much advantage can be gained by the general application of inclined plates; but by

restricting the application of deflecting armor to certain structural combinations, great advantage, both in the reduction of weight and increased protection can be obtained by its use.

The Confederate armored vessels *Atlanta* and *Tennessee* had the plates of their casemates inclined at an angle of about 30°, such a disposition constricted the interior space and thereby interfered with the proper working of the guns, while it is doubtful if there was much gain from the deflective action, and consequently of weight at so large an angle. The same interior space, defended by an equal weight of vertical armor, would probably give almost as great a measure of protection; but this disposition had this advantage for the Confederates, it enabled them to obtain a greater measure of protection with the light plating, which their meagre facilities permitted them to produce, than could have been obtained by a vertical disposition of the same thickness of plating. In the plans herewith presented it is intended to keep the angle of incidence down to a maximum of 15°.

Curved deflecting armor will give great advantages over that having plane inclined sides, owing to the angle of clearance which the curve affords. The Confederates used curved deflecting armor in the construction of the Hollins' ram which, above the water, was of a turtle back form. The difficulty here encountered was that by enveloping the entire exterior of the vessel in armor, in order to obtain a sufficient margin of buoyancy, the horizontal angle of incidence was made so great that but little advantage was obtained from the deflective principle; while on the other hand if the horizontal angle of incidence was made sufficiently acute, by deeply submerging the vessel, the margin of buoyancy would be so much reduced as to render her liable to sink by the admission of a very small amount of water. These difficulties are overcome in the design of vessel herein described, by the combination of a curved shield with the hull of an ordinary vessel, producing an interior turtle back; the space above the curved shield being divided into water-tight compartments to be packed with water excluding stores, thereby giving a large margin of buoyancy, or life belt to the vessel.

By the aid of this combination of shield, hull and life belt, very acute angles of incidence at the water line are obtained for horizontal fire, whereby a large measure of protection is obtained with very light plating.

In the form of deflective vessel, in which the entire superstructure

is enveloped in armor, the height above the water is not sufficient to admit of the working of guns, such a design being only applicable to rams or torpedo boats. But in the form of vessel herein described the guns are mounted in separate shields far above the water line, the armor serving as a carriage for the gun, which being breech loading needs but a small protected space for its crew at the breech end; by this means the guns' crews are completely protected with the least possible weight of armor.

The zone of danger is the side of the vessel, alternately acted on by wind or water as the ship rolls. It is proposed to protect this vital part by interior deflecting armor. The position of the shield in relation to the water-line to be adjusted by the admission of water to the double bottom.

In combats between ships at ordinary fighting range, horizontal fire is all that need be considered—a vertical target can easily be struck, while it is almost impossible to make a projectile fired from a vessel rolling at sea strike a horizontal surface. Under such circumstances it would be very difficult to land a shot upon the area of an hundred-acre farm, to say nothing of the much smaller surface of a ship's deck. Curved fire from land batteries placed for the defence of channels is most effective, but such fire is impracticable in contests between vessels at sea, as an entire shipload of ammunition might be expended before making one successful shot.

When elongated shot fired from rifled guns strike the water, they tumble end over end and sink beneath the surface, and there is probably no instance known of such a shot striking a vessel below the water-line, unless her side was exposed by rolling. When the combatants are a certain distance apart, the intervening water serves as an impenetrable rampart for that portion of the ship below its surface. For every depression below the mean level of the water there is a corresponding elevation or protuberance above it; and these elevations or protuberances above the mean surface will most effectually deflect shot of high energy, and protect the side of the vessel below them; therefore, a vessel would not be exposed by the hollows between two waves, and if she was, a plane-sided shield would have no advantage over a curved one.

Figure 1 represents a cross section of a cruising vessel rolling in a sea way, being struck by a projectile which is deflected upwardly through the light penetrable upper works. This shield conforming to

the arc of a circle, described from a centre approximating the ship's centre of oscillation, presents a practically constant angle of incidence to horizontal fire as the ship rolls. It is not claimed that the curve of a circle will give the most constant angle of incidence to horizontal fire, as such would not be the case, for the true curve would partake somewhat of the nature of that of a parabola, and would, however, vary slightly with each change of the load or draught of the vessel; but the curve of a circle is an approximation near enough for practical purposes, and has the advantage of giving more protected space under the shield for boilers and machinery, and less room above it for water to enter, to endanger the buoyancy and stability of the ship; where it diverges from the true curve it is in the most advantageous direction.

Figure 2 represents a cross section of a turreted vessel having vertical side armor and horizontal deck plating, being struck by a projectile under similar circumstances to Fig. 1; the projectile penetrating the vertical armor and impinging against the under surface of the armored deck, is deflected downward through the bottom of the vessel, passing through one of the boilers on its way.

Figure 3 represents the plan view of the vertical *V* turret *A*, (Fig. 1) and Fig. 4 represents the plan view of the cylindrical turret *B* (Fig. 2), with the action of projectiles upon the same, respectively.

The portion of a deflecting shield, of any form, liable to be struck at any given instant consists of a zone of small area situated above, at, and very slightly below the mean water-level. This small imaginary zone is shifting in character, and on a curved shield of five feet rise, extending four feet below and one foot above the water-line, it would probably be about 18″ in height. The curved shield covers the entire zone of danger, five feet in height; and this smaller zone, consisting of the part liable to be struck by horizontal fire at any given instant, traverses the larger zone, more or less, according to the oscillations of the vessel, and protects it in detail by constantly presenting a great horizontal thickness of armor, with a very acute angle of incidence, and a very large angle of clearance to the part where the vast majority of shot strike.

Figure 5 represents a cross section of a cruiser, and three different forms of deflecting shields, numbered respectively 1, 2 and 3. They each have the same immersion, being secured to the sides of the vessel four feet below the water-line, and Nos. 1 and 2 rise one foot above it; but the angle of the plane-sided shield No. 3 being equal to the

is enveloped in armor, the height above the water is not sufficient to admit of the working of guns, such a design being only applicable to rams or torpedo boats. But in the form of vessel herein described the guns are mounted in separate shields far above the water line, the armor serving as a carriage for the gun, which being breech loading needs but a small protected space for its crew at the breech end; by this means the guns' crews are completely protected with the least possible weight of armor.

The zone of danger is the side of the vessel, alternately acted on by wind or water as the ship rolls. It is proposed to protect this vital part by interior deflecting armor. The position of the shield in relation to the water-line to be adjusted by the admission of water to the double bottom.

In combats between ships at ordinary fighting range, horizontal fire is all that need be considered—a vertical target can easily be struck, while it is almost impossible to make a projectile fired from a vessel rolling at sea strike a horizontal surface. Under such circumstances it would be very difficult to land a shot upon the area of an hundred-acre farm, to say nothing of the much smaller surface of a ship's deck. Curved fire from land batteries placed for the defence of channels is most effective, but such fire is impracticable in contests between vessels at sea, as an entire shipload of ammunition might be expended before making one successful shot.

When elongated shot fired from rifled guns strike the water, they tumble end over end and sink beneath the surface, and there is probably no instance known of such a shot striking a vessel below the water-line, unless her side was exposed by rolling. When the combatants are a certain distance apart, the intervening water serves as an impenetrable rampart for that portion of the ship below its surface. For every depression below the mean level of the water there is a corresponding elevation or protuberance above it; and these elevations or protuberances above the mean surface will most effectually deflect shot of high energy, and protect the side of the vessel below them; therefore, a vessel would not be exposed by the hollows between two waves, and if she was, a plane-sided shield would have no advantage over a curved one.

Figure 1 represents a cross section of a cruising vessel rolling in a sea way, being struck by a projectile which is deflected upwardly through the light penetrable upper works. This shield conforming to

the arc of a circle, described from a centre approximating the ship's centre of oscillation, presents a practically constant angle of incidence to horizontal fire as the ship rolls. It is not claimed that the curve of a circle will give the most constant angle of incidence to horizontal fire, as such would not be the case, for the true curve would partake somewhat of the nature of that of a parabola, and would, however, vary slightly with each change of the load or draught of the vessel; but the curve of a circle is an approximation near enough for practical purposes, and has the advantage of giving more protected space under the shield for boilers and machinery, and less room above it for water to enter, to endanger the buoyancy and stability of the ship; where it diverges from the true curve it is in the most advantageous direction.

Figure 2 represents a cross section of a turreted vessel having vertical side armor and horizontal deck plating, being struck by a projectile under similar circumstances to Fig. 1; the projectile penetrating the vertical armor and impinging against the under surface of the armored deck, is deflected downward through the bottom of the vessel, passing through one of the boilers on its way.

Figure 3 represents the plan view of the vertical *V* turret *A*, (Fig. 1) and Fig. 4 represents the plan view of the cylindrical turret *B* (Fig. 2), with the action of projectiles upon the same, respectively.

The portion of a deflecting shield, of any form, liable to be struck at any given instant consists of a zone of small area situated above, at, and very slightly below the mean water-level. This small imaginary zone is shifting in character, and on a curved shield of five feet rise, extending four feet below and one foot above the water-line, it would probably be about 18″ in height. The curved shield covers the entire zone of danger, five feet in height; and this smaller zone, consisting of the part liable to be struck by horizontal fire at any given instant, traverses the larger zone, more or less, according to the oscillations of the vessel, and protects it in detail by constantly presenting a great horizontal thickness of armor, with a very acute angle of incidence, and a very large angle of clearance to the part where the vast majority of shot strike.

Figure 5 represents a cross section of a cruiser, and three different forms of deflecting shields, numbered respectively 1, 2 and 3. They each have the same immersion, being secured to the sides of the vessel four feet below the water-line, and Nos. 1 and 2 rise one foot above it; but the angle of the plane-sided shield No. 3 being equal to the

angle of incidence of the curved shield No. 2 at the water-line, does not carry it to the same height.

No. 1 is the plane-sided shield proposed by the Naval Advisory Board for the cruiser Chicago, being the *fac-simile* of the official drawing. This shield presents so large an angle to horizontal shot at the water-line that it will afford no adequate protection with the light plating of 1½ inches proposed. Besides presenting too large an angle to give protection, it also weighs considerably more than Nos. 2 and 3.

No. 2 is the curved deflecting shield—the form of water-line defence recommended by Act of Congress of August 5th, 1882, authorizing construction of new cruisers—conforming in cross section to the arc of a circle, and presenting a practically constant angle of impingement to horizontal fire at the water-line as the ship rolls, and that so acute as to make penetration very difficult with comparatively light plating.

A horizontal shot at the water-line would strike the curved shield at *G*; as the line *IT* is tangent to the arc at the point of initial impingement, it therefore represents the angle of the same.

The fact being that more shot would strike the curved shield above the water-line than below it, it is therefore making a concession to take *G* as the average angle, as, practically, the mean angle would be much less; and it should also be remembered that *G* is the initial angle of impingement, which, owing to the curved surface, rapidly diminishes as the shot glances along the plate. Such a curved shield would therefore possess a much greater deflecting efficiency than a plane-sided one, presenting the same angle of impingement, like Nos. 1 and 3, the angles of which would not decrease as the shot glanced along their surfaces, but would be liable to buckle up in front of the shot and be pierced by it; a contingency that would not arise with the curved shield, presenting the same angle, as the shot, owing to the curve, can much more easily free itself from the surface of the armor.

Shield No. 3 is drawn for the purpose of proving that it is impossible to construct a shield, having plane inclined sides, that will present so acute an angle to horizontal fire as the curved shield No. 2; or that will give as much room under it for boilers and machinery; or that will exclude the same amount of water from the part of the vessel above it; or that will give the same strength and stiffness to a vessel.

The line *AE'* is drawn parallel to the tangent *IT*, and the horizontal water-line cuts it at *H*. As the line *AE'* is drawn parallel to the tangent *IT*, therefore the angles *G* and *H* are equal. And as this

angle will not carry the crown of the plane-sided shield to the same height as the crown of the curved shield, the plane-sided shield will require a greater angle to attain the same height.

It will be apparent that the curved shield No. 2 contains under it the space represented by the segment contained between the arc *AGE* and its chord *AE'*, in addition to that contained under the plane-sided shield No. 3.

Also as the segment is above No. 3 and below No. 2, the former will admit a volume of water into the ship above it, equal in cross section to the area of the segment *AGEAE'*, to endanger the buoyancy and stability of the vessel, which the round-up of the curved shield No. 2 would exclude.

The curved shield No. 2 is superior in these particulars to the plane-sided shield No. 1, or any other plane-sided shield, presenting the same angle, that can be constructed:

1st. It presents a more acute, and, practically, constant angle of impingement to horizontal fire, and one that with a moderate thickness of plating, if supplemented with coal or stores in water-tight compartments to augment the deflecting efficiency and exclude water, would afford a very substantial resistance to the fire of heavy guns, while the plane-sided shield would afford but a very small measure of protection.

2d. The plane-sided shield No. 1 would weigh considerably more than the curved shield No. 2, and would encumber a ship with the weight of armor without giving her the benefit of its protection.

3d. The curved shield, if anything like the same angle of impingement is presented, will contain much more room under it, for boilers and machinery, than an inclined plane shield, and is therefore admirably adopted for light draught vessels intended for service in the shoal waters of our Atlantic and Gulf coasts.

4th. With an equal angle of impingement, the round-up of the curved shield would exclude a large volume of water, which the plane-sided shield would permit to enter, and endanger the buoyancy and stability of the vessel.

5th. The curved shield will possess a much greater deflecting efficiency with any given angle, owing to the fact that the angle of clearance is a constantly increasing one, so that projectiles which would readily pierce a plane-sided shield can free themselves from the surface of the curved shield.

6th. The curved shield, tied in by the chords of its arc and supported on longitudinal and transverse bulkheads, in combination with the ships cellular bottom and sides, will give a vessel an efficiency and strength as a ram that is unprecedented. A vessel so built would form a scientifically constructed floating girder, having such rigidity as would permit of her being engined with the highest power. The curved shield with coal or stores above it, to augment the deflecting efficiency and exclude water, thereby serving as a life-belt for the vessel, would make a ship almost unsinkable, while the plane-sided one would be such an element of weakness that a vessel fitted with it could only, with difficulty, be kept afloat in action.

In regard to the deflecting efficiency of light plates, disposed at an acute angle, the British Admiralty have made experiments at Portsmouth within the last two years for the purpose of testing deck armor, proving that a two-inch iron plate, entirely unbacked, simply supported on beams, disposed at an angle of 10°, would resist the penetrating power of the 18-ton, 10-inch gun; and that iron plates of three inches thickness, similarly placed, and disposed at an angle of 15°, would throw off shot from the same gun discharged from a distance of 100 yards.

If such good practical results can be obtained from iron plates, it is reasonable to expect that a much greater efficiency can be derived from homogeneous steel plates, combining hardness with toughness.

To determine the relative deflecting power of the curved and plane-sided shields in the absence of any very extensive experiments on inclined plates, we can only reason from results obtained with vertical armor, and, hence, to form a fair comparison it is reasonable to suppose that in all cases the velocity of the shot, resolved in a direction normal to the plates, is entirely destroyed, and that the striking force in each case will be that due to a shot of the same weight moving normal to the plate with a velocity equal to the normal velocity of the shot moving obliquely to the plate.

The penetrating power of the shot being measured by its intrinsic energy, or by $\frac{w \cdot v^2}{2g}$, then, on inclined plates the striking force would be $\frac{w \cdot v^2 \sin^2\theta}{2g}$, where θ is the angle between the direction of the shot and the tangent to the plate at the point of contact.

In the diagram, Figure 6, draw the tangent to the curve at the

water line, and lay off on the horizontal line a distance AO to represent v^2, draw AC parallel and OC normal to the tangent OT; lay off OB equal to OC, drop the perpendicular BD, then OD will equal $v^2 \sin^2\theta$, θ being the angle of inclination of the tangent to the horizon. Proceeding in the same way with the plane-sided shield, denoting the corresponding lines by corresponding letters, $O'D'$ will eqnal $v^2 \sin^2\theta'$, where θ' is the angle of inclination of the plane-sided shield to the horizon. The striking force exerted against the shields respectively will be represented by these lines multiplied by the same constant, and the relative protection afforded will be inversely as the lines, or as 5.4 to 1 in favor of the curved shield. But when it is taken into consideration that the curved shield allows the projectile to clear itself after striking, by a considerably increasing angle of clearance, between the curve OF and the tangent OT, it is evident that this ratio of protection will be consideraly increased in favor of the curved shield.

The other method of comparing the relative efficiency of the two shields is to measure the metal that would have to be displaced to effect penetration. In the case of the curved shield the distance through WR is $9\frac{3}{16}''$, there being $1\frac{0}{16}''$ greater distance through the metal of the curved shield than through a plane-sided shield presenting the same angle. The distance HI through the metal of the plane-sided shield No. 1 is only $3\frac{1}{4}''$.

In the case of vertical armor, experience has demonstrated that the energy required to penetrate plates of different thickness is proportional to the square of the thickness of the plate; and reasoning from this, we are led to conclude that in the case of inclined plates it will vary as the square of the distance measured through on a line making the same angle with the plate that the plate makes with the horizon.

Taking the shield before mentioned, the distance through, as measured on the water-line, in the case of shield No. 1, is $3\frac{1}{4}$ inches, and in the case of shield No. 3 the distance measures $7\frac{1}{16}$ inches, and the efficiency of the two shields would be directly as the squares of these quantities, or as 1 to 5·4. But as the curved shield affords a greater distance through, and allows the shot in glancing to clear itself more readily than a plane shield, it will be much more efficient than the above proportions show.

Notwithstanding the fact that the great superiority of the curved shield over the plane can be proved by unanswerable mathematical demonstrations, Lieutenant Very, a member of the Naval Advisory

Board, in his able and interesting article, "The Development of Armor for Naval Use" (No. 25, Proceedings U. S. Naval Institute), takes peremptory ground in favor of the plane over the curved shield; but I propose to show that both his premises and conclusions are erroneous.

On page 527 will be found this statement in reference to the comparative merits of the two shields: "In the United States it has been made a matter of much discussion whether this alteration from a curved to an angular disposition is an improvement, or a step backward. It seems, however, to be easily susceptible of proof that the angular arrangement presents most decided advantages." Upon the same page is the diagram Fig. 8, representing a curved and a plane shield on the same cross section, with the outline of a boiler *K* in position under them, for comparison. The top of the plane shield is represented as entirely below the water line, while the crown of the curved one rises far above it; but fairness of comparison in boiler capacity, under the two shields, required that both should have been given the same vertical height.

A casual, or an unscientific reader, from "a great respect for official utterances," might give this unqualified claim of "most decided advantages" of the plane over the curved shield, its face value, but a critical examination of the diagram with its explanatory context will show the claim to be unfounded. It is generally true that any theory is "easily susceptible of proof" where its advocate is allowed to make his own premises, but Lieutenant Very has failed even to draw correct conclusions from his voluntary assumptions.

The only special advantage claimed by Lieutenant Very—with the aid of his incorrect diagram, which can be conceded—is a very slight decrease of angle of the plane over the curve at the point *D* four feet below the water line, where projectiles virtually never strike. But when it is considered that this slight disadvantage for the curved shield at the point mentioned, is accompanied by a corresponding decrease of the angle of curve over the plane at the top of the shield, where essentially all projectiles do strike, this very slight advantage is conceded, admitting for this argument Lieutenant Very's delusive diagram. I am not advocating protection to that part of a ship where it is practically invulnerable to shot.

There have been winds so fierce as to destroy the strongest structures on shore, and there have been storms so violent as to founder the

staunchest ships at sea, and lightning so powerful as to make sport and fragments of either. Against such unusual incidents, intense as is the love of life, it has not been within the power of human thought adequately to provide. If men should seek to do it they would never build ships nor houses, but live in caves, and then not be absolutely safe from these immeasurable and irresistible forces. Such dangers are the inevitable risks of our living at all, and we build ships and go to sea in them, and build houses and live in them, and takes these risks, and we would be mere savages if we did not. In this category of extremely improbable chances would come the likelihood of a ship being struck by a projectile four feet below the water line during an engagement. Such a thing *may* happen, but experience shows that it is no more likely to occur than than the disasters of nature mentioned above.

Lieutenant Very quotes the geometrical axiom, "a straight line is the shortest distance between two points," a truth which no one will dispute, but what application it has to the question at issue is not so clear; as the outline of the plane shield is not represented by a single straight line, but of three straight lines with considerable angles at their points of intersection, and any one can see by referring to Fig. 5, that the arc of a circle representing the outline of a curved shield would be of less length than the three lines representing the plane-sided shield, and that a curved shield would weigh less than a plane-sided one of equal height.

If the curved and plane shields, represented in the diagram on page 527, were correctly shown as of equal height, the advantage in weight would be in favor of the curved; but the advocates of the plane are welcome to the infinitesmal advantage in this respect apparently obtained by the diagram.

This drawing also contains the outline of a boiler *K* in position under the shields, and the statement has been made by members of the Naval Advisory Board that the curved shield will not cover as great a height of boiler as the plane-sided one. This assertion is also incorrect, as an inspection of the diagram will show. If the boilers are set close out against the side of the vessel, no advantage whatever in height of protected space would be obtained by the curved shield, as the top of the boilers would have to be placed more than four feet below the water line, the same as when placed below a flat, under-water, armored deck, similar to that of the *Comus* class.

The top of the shield being placed below the water-line, if the sides of the vessel should be penetrated, then when the water-excluding stores are exhausted from the compartments above it, the *Comus* flat-deck would permit water to flow in and sink the vessel. The top of the shield should rise somewhat above the water-line in order to give the vessel a margin of buoyancy independent of the water-excluding stores.

If the boilers are placed part way out, in the position shown on the diagram Fig. 8, only a small measure of protection is obtained by the shield, owing to the large angle of incidence presented; and if they were placed all the way out at the same height, the shield would degenerate into vertical armor.

But any one can see, by referring to Fig. 8, that if the boilers are placed in their proper position, in the centre of the vessel, the curved shield there represented will cover a much higher boiler than the plane-sided one.

Lieutenant Very should not object to his own diagram proving more than he intended, for it only shows that in its construction he built wiser than he knew.

Such a disposition of the boilers will give the following advantages over that shown in the diagram, viz., it will admit of a central longitudinal bulkhead, dividing the under-water body into water-tight compartments, a device with which all large vessels should be provided; it affords greater safety to the boilers from the attack of torpedoes and rams in time of war, and danger from collision; it enables the firemen to obtain coal from side bunkers, or chutes from compartments above, directly in front of their furnace doors.

The greater height of protected space in the centre of the vessel afforded by the curved shield could be made available either by arranging the boilers with side fire-rooms, for which there is ample room, or by disposing them with athwartship fire-rooms.

A large proportion of the coal and stores should be carried in the compartments above the shield, to augment the deflective efficiency and exclude water, the effect on the stability of the ship being compensated for, when occasion requires it, by the admission of water to the double bottom. This would allow nearly all the space under the shield to be utilized for boilers, machinery and magazines, with passages from the same to the different guns. The stout tubes for training the vertical V shields by power applied beneath the curved shield,

also serve as conduits for conveying ammunition directly to the breech of the guns. By this means all exposure of men by the transportation of ammunition along the open deck is avoided.

Lieutenant Very makes the following statement on page 529; "It has been shown heretofore that a thickness of armor for the shield of less than four inches can scarcely be depended on at a greater angle than 20°. The average angle necessary for this shield is from 22° to 28°." These statements are strictly true, yet he, with a knowledge of these facts, as a member of the Naval Advisory Board proposed to apply $1\frac{1}{2}''$ thickness of plating to all the new ships in the form of plane shields disposed at angles of 27° and 28°, having a horizontal thickness of only $3\frac{1}{4}''$, while a curved shield of considerably less weight, covering boilers of equal height, would present and angle of only 13°, and a horizontal thichness at the water-line of $9\frac{3}{16}''$, which would afford eight times the resistance of the plane.

An examination of the next statement on page 529 proves it to be widely incorrect; "Where a two inch deck curved with a single radius is put in, the same weight would allow with the chord disposition, 4 inch plates on the side chords and $1\frac{1}{2}$ inch on the dead flat." Taking the cruiser *Chicago*, the ship of greatest beam, and therefore the one most favorable for the above hypothesis, we find the area of the flat top is not more than one-eighth greater than the area of the side planes. It would therefore be impossible to increase the thickness of the side planes more than $\frac{3}{8}$ of an inch by taking a half inch from the flat top, although two inches are claimed by Lieutenant Very. In the ships of less beam, *Boston* and *Atlanta*, a half inch taken from the flat top would not increase the thickness of the side planes as much as $\frac{3}{8}$ of an inch.

If the thickness of the sides of the plane shield can be augmented at the expense of the top, so likewise can the sides of the curved shield be increased in thickness at the expense of the top, by the application of taper plates; it is therefore not worth while to take this feature into consideration when comparing the merits of the two shields.

Lieutenant Very says on page 527: "The shield has now become universally recognized as a necessary attachment to all vessels, both armored and unarmored;" meaning of course the plane-sided form, to which he appears to be peculiarly attached, and on page 524 he lays great stress upon the importance of having the shield *well supported against flexure*, a point well taken, and I will ask which will

give, and which will require the most rigid support, the curved or the plane-sided shield? Undoubtedly the arched curve will afford the most unyielding support, while the plane-sided shield not giving so much, would require far more to enable it to deflect projectiles, as it does not possess the angle of clearance obtained by the curve.

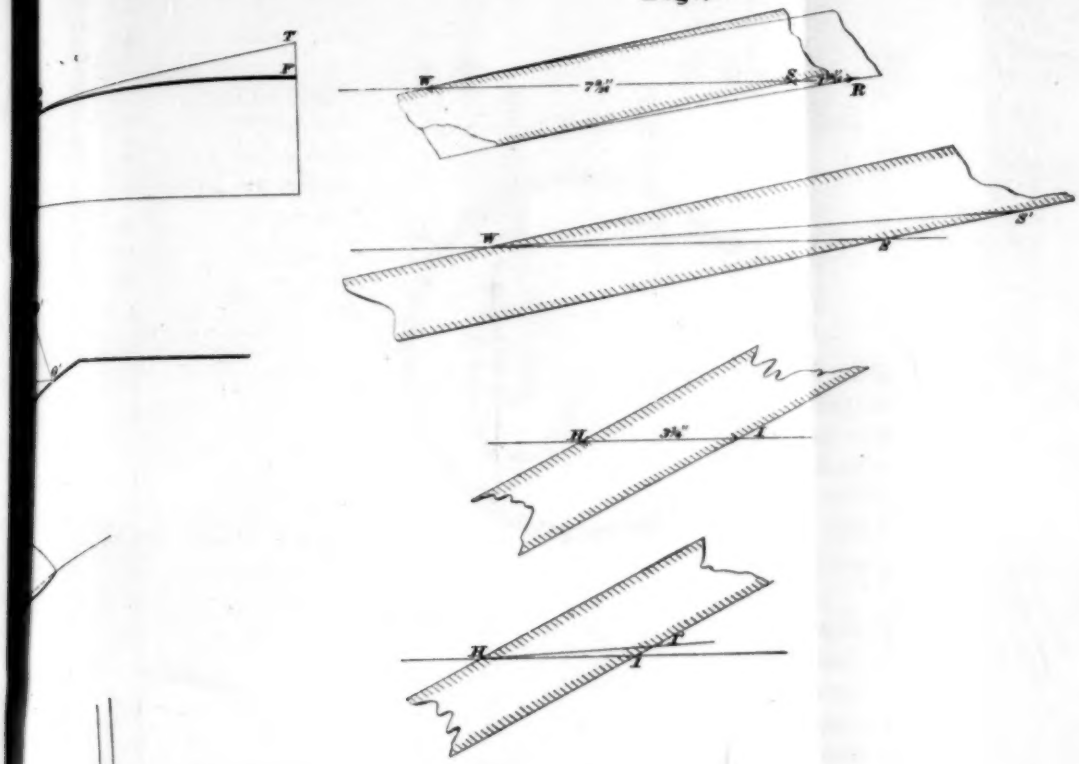
In a plane shield of such light plating as $1\frac{1}{2}''$, disposed at so large an angle as 27°, the resistance would be so small in comparison to the power of the guns likely to be brought against it, that the full effect of the horizontal distance through the plating would not be obtained; as the tendency, in such cases of disproportioned resistance to projectile force, is for the shot to turn in a direction normal to the surface of the plate; the reason of this is, as the projectile passes through the plate, there is a less thickness of metal under it than there is above it, and it follows the line of the least resistance; even light, at its immense velocity, follows the same general law; therefore, such a weak shield, aside from its affording no adequate protection, would be a positive source of danger in itself, from the downward deflection of projectiles, while a curved shield of equal thickness and less weight, presenting a much more acute angle of incidence, with a constantly increasing angle of clearance, would invariably deflect shot upwards.

Figure 5 is a fair and correct diagram for comparing the merits of the curved with the plane-sided shield, as both are of the same height, each being secured to the sides of the vessel four feet below the water line, and rising one foot above it.

With such a curved shield as No. 2, Fig. 5, of two inches thickness of plating, the horizontal distance through the plating on the water line would be 12·25″, and the angle presented at the same point would be 13°, while the horizontal distance through a plane-sided shield similar to No. 1, Fig. 5, of the same thickness of plating, would be 4·33″, and the angle presented would be 27°. This angle would of course be the same at all depths, and would be the average of the angles, in all positions, which would sometimes be greater and sometimes less, as the vessel rolled.

The horizontal angle of incidence of the curve would be practically constant in all positions, and the horizontal thicknesses of plating, and ratios of superiority of the curve over the plane at different points of immersion, would be as follows, viz:

Fig.7.



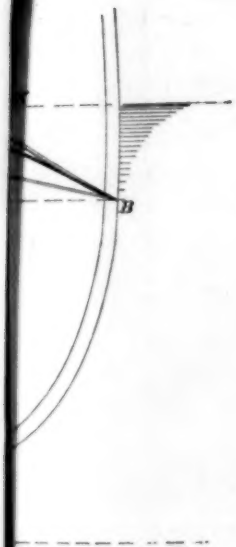


Fig.8.

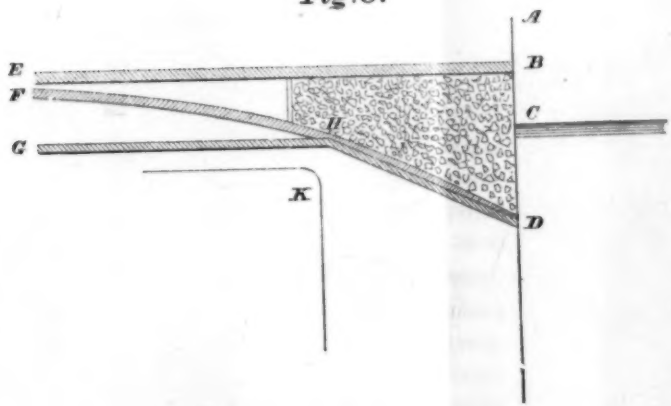


Fig. 1.

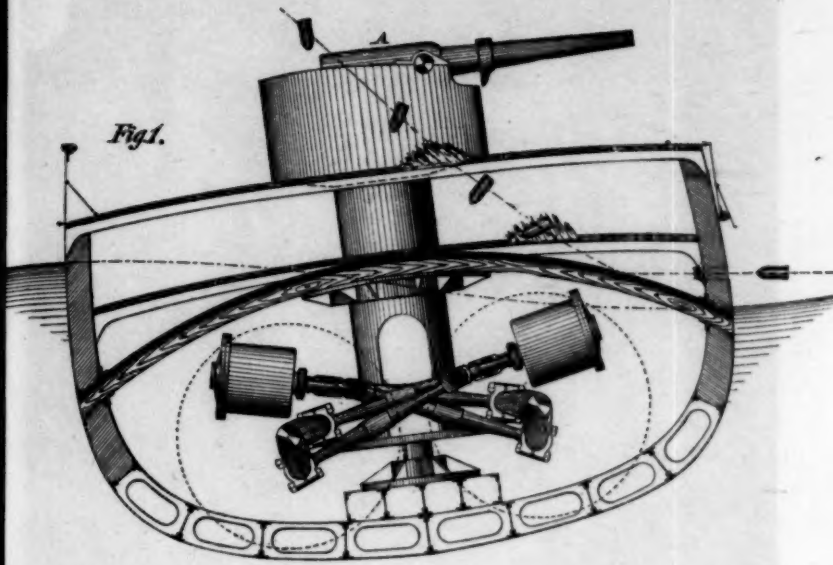
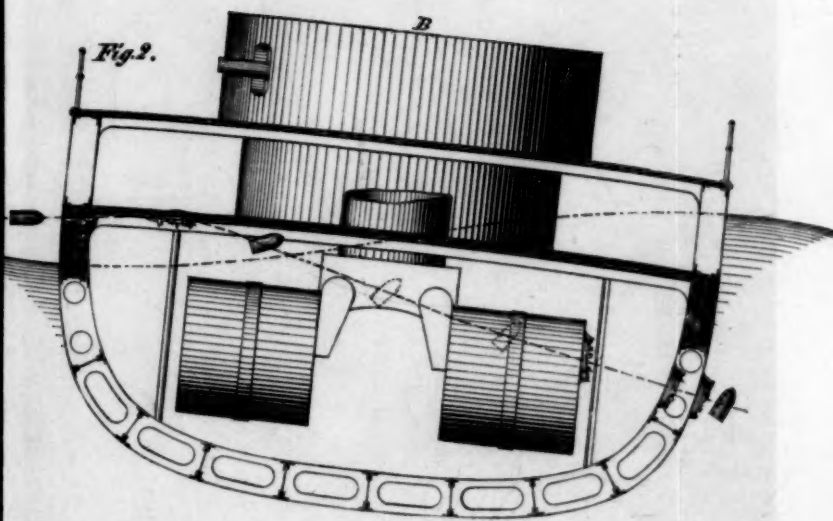


Fig. 2.



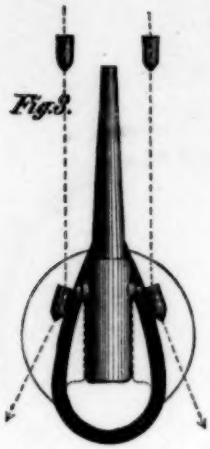


Fig.3.

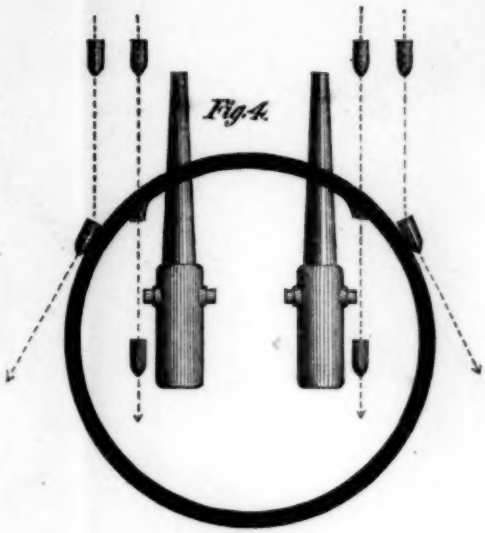


Fig.4.

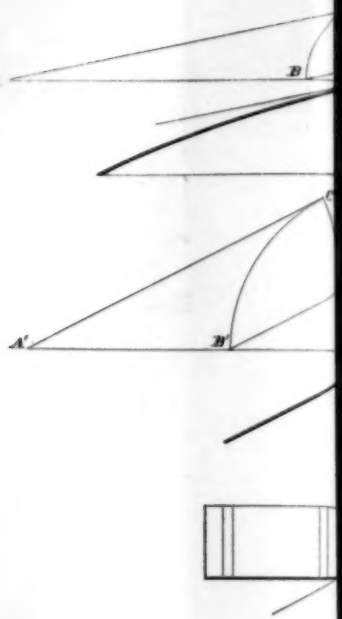
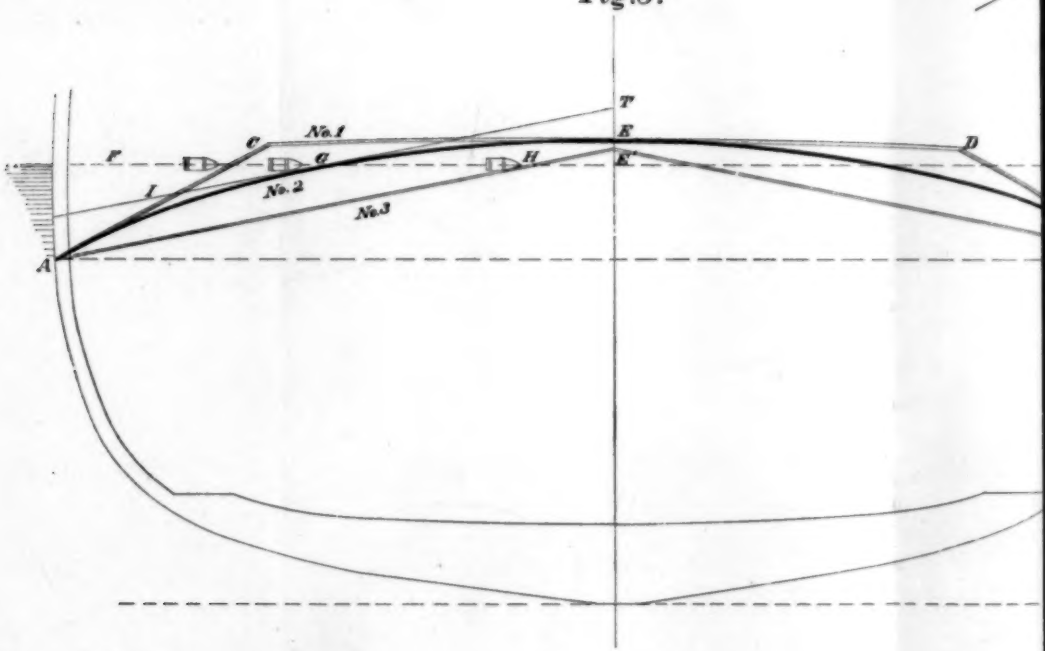


Fig.5.



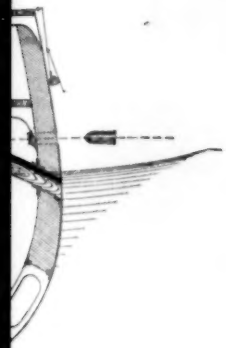


Fig.3.

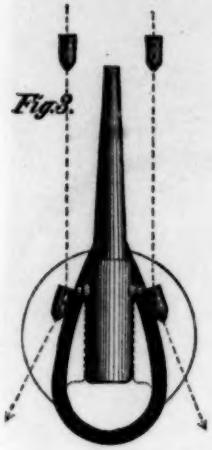


Fig.4.

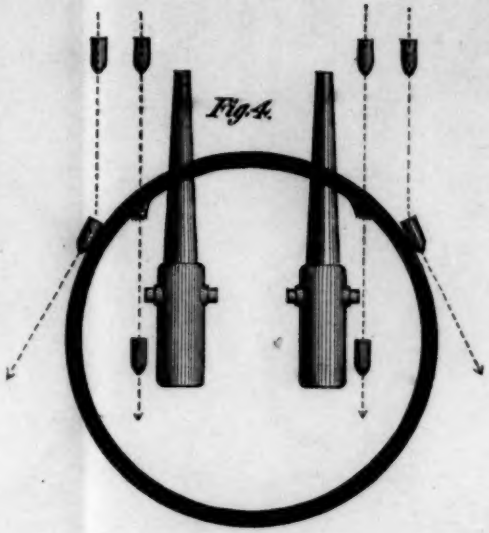
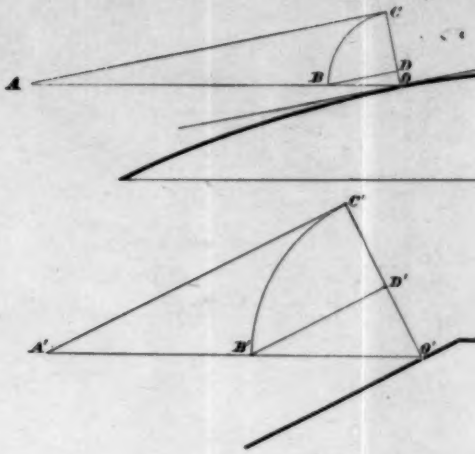


Fig.6.



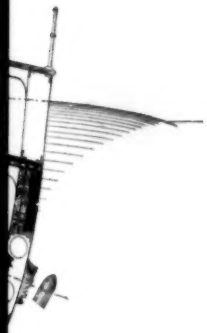
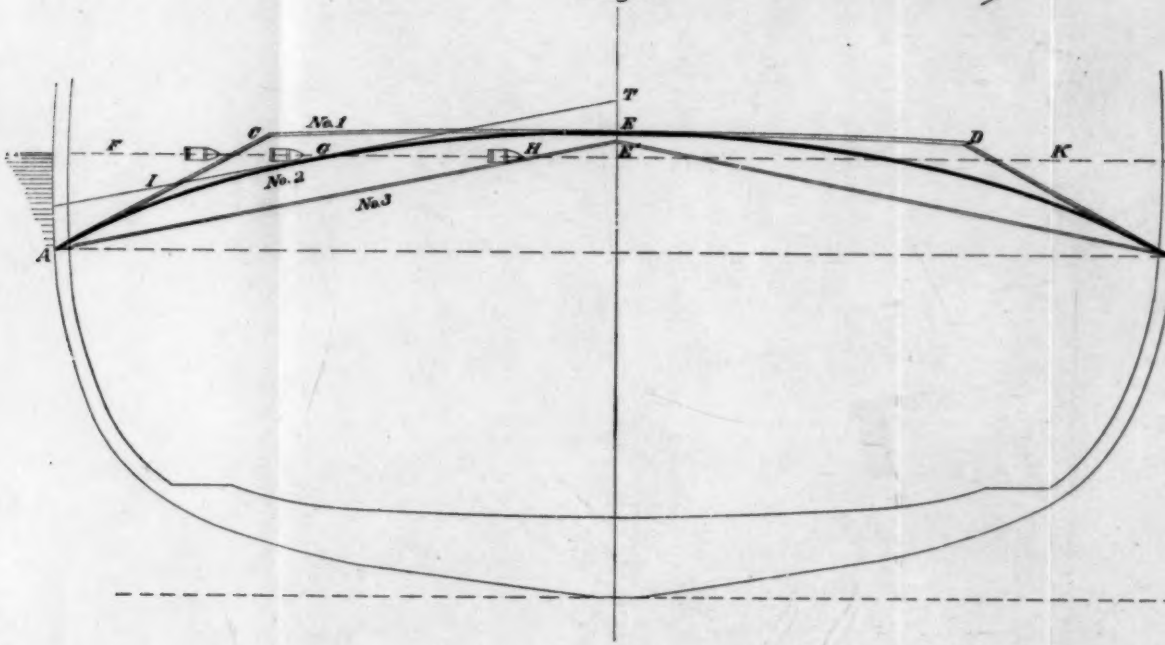


Fig.5.



6.

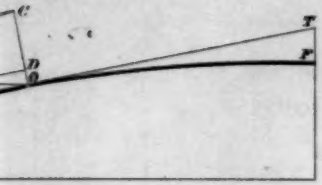


Fig.7.

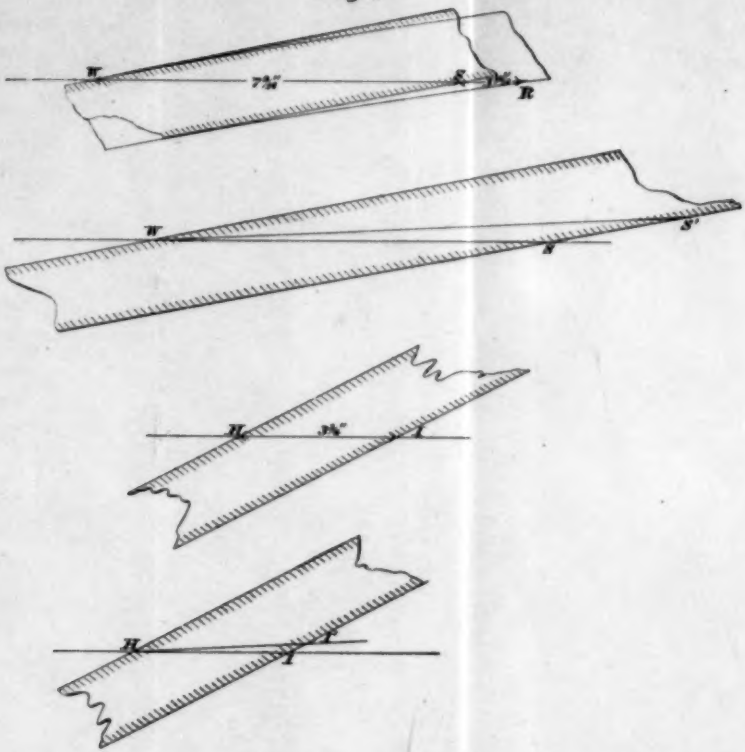
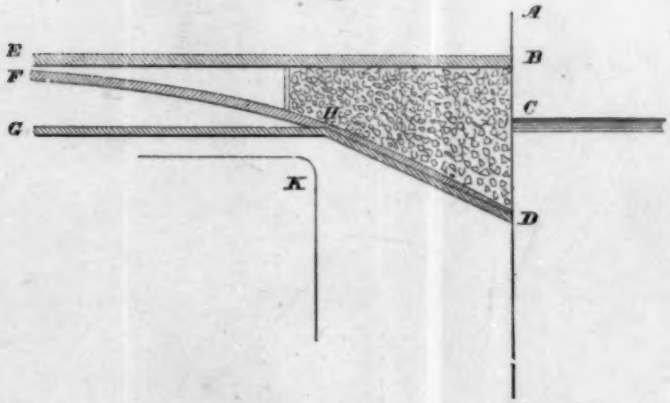


Fig.8.



give, a
the pl
the m
so mu
does n
In
an an
power
of the
as the
tile fo
the pl
plate,
and it
veloci
aside
source
while
much
of cl
Fi
the c
each
line,
W
of p
line
be 1
simi
4·33
cour
angl
time
T
cons
ratio
imm

	Horizontal thickness.	Superiority of curve over plane.
6″ above water line	18·5″	17·72 to 1
water line	12·25″	8 to 1
6″ below water-line	9″	4·32 to 1
12″ below water-line	7·75″	3·20 to 1
18″ below water-line	7″	2·61 to 1
24″ below water-line	6·25″	2·08 to 1
30″ below water-line	5·5″	1·61 to 1
36″ below water-line	5·25″	1·47 to 1
42″ below water-line	5″	1·32 to 1
48″ below water-line	4·75″	1·20 to 1

From the above list of horizontal thicknesses of plating, and ratios of resistance at different depths of immersion, it will be seen that one of the chief merits of the curve is that it keeps its greatest angle and least horizontal thickness of plating safely submerged at a considerable depth below the water line, where shot cannot strike it; but where protection is most required, the curved shield gives the greatest thickness of plating, the most acute angle of incidence, and the largest angle of clearance, automatically adjusting the same as the vessel rolls.

A curved shield of two inches in thickness, presenting an angle of 13° at the water line, and a horizontal distance through the plating of 12·25″, would give double the resistance of a plane-sided shield of 4″ thickness presenting an angle of 27°, and having a horizontal distance through the metal of 8·66″, as the squares of these numbers would be 150 and 74·99, or a ratio of 2 to 1 in favor of the curve, omitting the advantage of the large angle of clearance afforded by the curve; which also applies to all the ratios.

(To be continued.)

Circulation of Solar Energy.—M. Duponchel calls attention to a work, printed in January, 1882, in which he stated that the actual facts of science in regard to the nature of light, heat, electricity and magnetism testify to the absolute conservation of the living force which is manifested under divers forms of motion. Many years ago he tried to explain how the compensations could be effected, which are necessary to maintain the energy, and how the heat which is emitted can return to the focus of departure, forming a closed current and a continuous circulation, analogous to that which results from the action of the heart upon the movements of the blood. The views which have lately been published by Siemens, have induced him to undertake a mathematical discussion of the question and to confirm the results of his theory by facts of observation.—*Rev. Scientif.*, Jan. 27, 1883. C.

ECONOMY OF COMPOUND ENGINES.

By WILLIAM DENNIS MARKS,
Whitney Professor of Dynamical Engineering, University of Pennsylvania.

The limits of profitable expansion are quite narrow, without the necessity arising of making assumptions, which may or may not be true, as regards condensation and re-evaporation of the steam used, and this statement is quite true therefore as regards a perfect gas expanding according to Marriotte's law.

Leakage aside, Mr. Hill's experiments would seem to prove that in the foremost types of simple engines at least one-fifth of the heat of the steam used does not appear on the diagram either as work or as steam heat voided at end of expansion.

That a fair comparative test has ever been made between single and compound engines under the imperative condition as to proper load and steam pressure the writer thinks is doubtful, since compound engines are almost always given higher steam pressures and lighter comparative loads than single engines.

The advantage of the compound engine must lie in its lesser condensation alone, other things being equal, and this diminution of condensation must compensate for the increased quantity of machinery demanded before we begin to consider its superiority.

This point must be considered experimentally by a careful determination of the ratio of the actual to the indicated steam and heat.

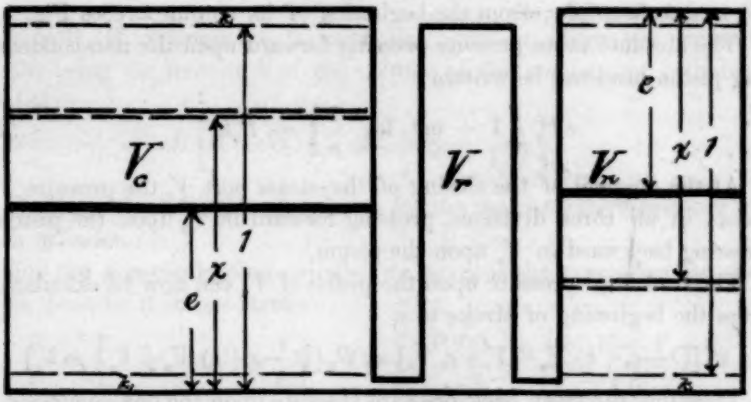
For the purpose of gaining a clear general, but not very exact idea, let us assume a perfect gas expanding according to Marriotte's law fed to a pair of compounded cylinders at a given initial pressure P_b and exhausted against a back pressure B outside of the cylinder. While these assumptions will not perfectly fulfill the conditions of steam, the results obtained will serve as a guide in the use of steam and by proper modifications can be applied to the steam engine itself. When steam is used the high initial temperature of the steam is communicated to the walls previously at or above the temperature of exhaust by means of the condensation of the steam which results in the water ready for re-evaporation at the instant of any diminution of pressure. That part of the cylinder walls subjected to initial steam being hotter than the expanded steam gives the steam this heat very readily which goes for the twofold purpose of recreating steam and of warming up to the

temperature of the steam the gradually uncovered walls of the cylinders which are at the temperature of the exhaust or perhaps above it.

These exchanges go on with a celerity not easily apprehended without thoughtful consideration of the great weight of iron in the steam cylinder and its conductivity for heat as compared with the relatively exceedingly small weight of steam and water at the temperature of evaporation which enter and leave the cylinder at each stroke.

Theories to the contrary, notwithstanding, it would it seem as if within the limits of economic expansion an equilateral hyperbola represents with quite as great approximation as any other curve the pressures of expanding steam in an iron cylinder steam-jacketed.

FIG. 1.



Taking then a perfect gas as our starting point. Assuming as the simplest case two cylinders with cranks 180 degrees apart

Let V_n = the true volume of the non-condensing cylinder (including one of its clearances k) up to its valve face.

Let V_r = the volume of the connecting channels (and receiver, if there is one) from valve face to valve face.

Let V_c = the true volume of the condensing cylinder (including one of its clearances k_1) up to its valve face.

Let e = the true cut-off of the non-condensing cylinder.

Let P_b = the initial pressure of the non-condensing cylinder. Pounds per square inch abs.

Let e_1 = the true cut-off of the condensing cylinder.

Let B = the back pressure of the condensing cylinder. Pounds per square inch abs.

After a compound engine has attained its regular work it has attained such a pressure P_r in the receiver (the word receiver will be used to comprise all pipes, steam-chest, etc., that may be between the two cylinders, whether there be a specially designed receiver or not) as will enable the condensing cylinder to void the same weight of vapor at each stroke as is received by the non-condensing cylinder at each stroke, and we can therefore write the equation

$$e P_b V_n = e_1 P_r V_c$$

$$P_r = \frac{e P_b V_n}{e_1 V_c} \qquad (1)$$

The pressure P_r is that occuring at the exact moment when the port to the non-condensing cylinder is closed, and when the piston head of V_c is at a distance e_1 from the beginning of its volume. (See Fig. 1.)

The absolute mean pressure pressing forward upon the non-condensing piston head can be written

$$e P_b \left[1 + \text{nat. log.} \frac{1}{e}\right] - P_b k \qquad (2)$$

At the moment of the closing of the steam port V_c the pressure P_r exists in all three divisions, pressing forward in V_c upon the piston pressing backward in V_n upon the piston.

The backward pressure upon the piston of V_n can now be calculated from the beginning of stroke to e_1.

$$P_r [(1-e_1+k)\ V_n + V_r + e_1\ V_c] = P_x [(1-x+k)\ V_n + V_r + x\ V_c]$$

Therefore the mean back pressure absolute upon the non-condensing piston, while the two pistons proceed in opposite directions through a fraction of the volume $(e_1 - k)$ is

$$\frac{P_r [(1-e_1+k)\ V_n + V_r + e_1 V_c]}{(V_c - V_n)} \text{ nat. log, } \frac{(1+k) V_n + V_r + (V_c - V_n) e_1}{(1+k) V_n + V_r + (V_c - V_n) k} \qquad (3)$$

This is also the forward pressure, absolute, upon the piston of the condensing cylinder.

When, now, the port of the condensing cylinder is closed, the two pressures part company, the back pressure in the non-condensing cylinder rising, and the vapor in the condensing cylinder expanding, and its pressure falling.

Let us consider first the back pressure in the non-condensing cylinder, while the piston moves through the fraction of the stroke $(1-e_1)$. We can write the following equation:

$$P_r[(1-e_1+k)\ V_n+V_r]=P_x[(1-x+k)\ V_n+V_r]$$

Therefore we have the mean absolute back pressure

$$\frac{P_r[(1-e_1+k)\ V_n+V_r]}{V_n}\ \text{nat. log.}\ \frac{V_r+V_n(1+k-e_1)}{V_r+V_n k} \tag{4}$$

Secondly, the forward expansion pressure in the condensing cylinder, after its port to the receiver is closed.

We can write the following equation:

$$P_r[e_1\ V_c]=P_x\ x\ V_c$$

Therefore its absolute mean pressure is

$$e_1\ P_r\ \text{nat. log.}\ \frac{1}{e_1} \tag{5}$$

Finally, if compression is used, the point at which compression begins being the fraction b of the volume of the condensing cylinder, we have

$$B\left[1-b\left(1-\text{nat. log.}-\frac{b}{k_1}\right)\right] \tag{6}$$

We can now write the expressions for the mean effective pressure in each cylinder.

For the non-condensing cylinder we have, as the expression for the work done by it in one stroke

$$V_n\left\{eP_b\left[1+\text{nat. log.}\ \frac{1}{e}\right]-P_b k-\frac{P_r[(1-e_1+k)\ V_n+V_r+e_1 V_c]}{(V_c-V_n)}\right.$$

$$\text{nat. log.}\ \frac{(1+k)\ V_n+V_r+(V_c-V_n)\ e_1}{(1+k)\ V_n+V_r+(V_c-V_n)\ k}-\frac{P_r[(1-e_1+k)V_n+V_r}{V_n}$$

$$\left.\text{nat. log.}\ \frac{V_r+V_n(1+k-e_1)}{V_r\times V_n k}\right\} \tag{7}$$

The expression for the work done by the condensing cylinder during one stroke is, if we assume $k=k_1$

$$V_c\left\{\frac{P_r[(1-e_1+k)\ V_n+V_r+e_1\ V_c]}{V_c-V_n}\ \text{nat. log.}\right.$$

$$\frac{(1+k)\ V_n+V_r+(V_c-V_n)\ e_1}{(1+k)\ V_n+V_r+(V_c-V_n)\ k_1}+e_1\ P_r\ \text{nat. log.}\ \frac{1}{e_1}$$

$$\left.-B\left[1-b\left(1-\text{nat. log.}\ \frac{b}{k_1}\right)\right]\right\} \tag{8}$$

For example:

Let $P_b = 100$ pounds per square inch, absolute.
Let $V_a = 2$, $V_r = 1$ and $V_e = 8$.
Let the expansion be 8 times. We must then
Let $e = \frac{1}{2}$ and $e_1 = \frac{1}{2}$.
Let $k = \frac{1}{10}$ and $k_1 = \frac{1}{10}$ and $b = k_1$.
Let $B = 3$ pounds per square inch, absolute.

From equation (1) we have

$$P_r = \frac{100}{4} = 25 \text{ pounds per square inch.}$$

Equation (7) will then give

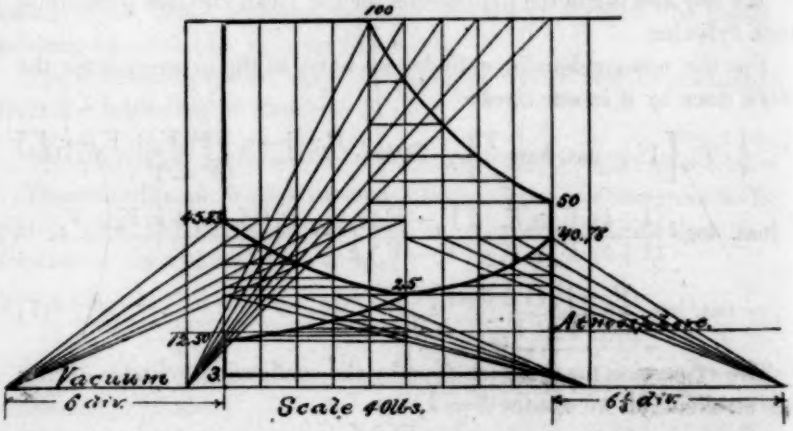
For the non-condensing cylinder $2\ \{84{\cdot}7 - 10 - 12{\cdot}63 - 14{\cdot}46\} = 95{\cdot}2$

For the condensing cylinder $8\ \{12{\cdot}63 + 8{\cdot}66 - 2{\cdot}7\} = 148{\cdot}7$

Total $243{\cdot}9$

These figures give the ratio of the horse-powers of the two cylinders. If we make V represent the area of the piston in square inches,

FIG. 2.



multiplied by the length of stroke plus clearance in feet, in formulas (7) and (8), we have at once the work done in one stroke by each cylinder from these formulas.

That is, in the formula for the horse-power

$$(\text{HP}) = \frac{PLAN}{33{,}000} \qquad (9)$$

We have the product of the factors *P.L.A.*, and need only to multiply this by *N* (the number of strokes per minute) and to divide by 33,000 in order to obtain the indicated horse-power.

Fig. 2 represents the combined diagrams of non-condensing and condensing cylinders for the example laid down to the same scale, being a graphical solution of the problem already analytically solved for a perfect gas.

No explanation is given, as it is but an extended application of the ordinary method of laying down a true hyperbola on a diagram, and therefore familiar to all engineers.

A little trouble will enable a comparison of all the expansion curves of indicator diagrams from compound engines with the isothermal curve.

The mean effective pressures, as taken from the diagram, will be found to exceed the calculated pressures in the analytical solution, because the true volume of the cylinder exceeds the volume through which the piston sweeps by the amount of the clearance at one end.

This fact should be borne in mind in using the analytical method.

The ultimate expansion by pressures is

$$E = \frac{P_b}{e_1 P_r} = \frac{V_c}{e V_a} \qquad (10)$$

That is to say, it is theoretically quite independent of the volume of the receiver, as also of the point of cut-off in the condensing cylinder.

If we fix the ultimate expansion *E* of the steam and the point of cut-off in the non-condensing cylinder we at once determine the ratio *R* of the volumes of the two cylinders

$$R = E_c = \frac{V_c}{V_a} \qquad (11)$$

In the problem stated already $E = 8$ and $e = \frac{1}{2}$

Therefore $$R = \frac{V_c}{V_a} = 4$$

This result is quite independent of any other considerations in the case of hyperbolic expansion.

* It would appear probable that an expansion greater than 8 to 10 is not commercially profitable in single engines in iron cylinders where steam is used, and condensed afterwards.

---

* See JOUR. FRANKLIN INST., Dec, 1883.

The English rarely exceed a ratio of volume R for the two cylinders greater than 4 and sometimes go as low as 2. We are obliged to look to them for precedents because of their practical monopoly of compound marine engine building for the United States.

Equation (11) becomes between these limits

$$e = \frac{R}{E} = \frac{2}{8} \text{ to } \frac{4}{8}$$

That is to say with the ratio of cylinders of from 2 to 4 and with the expansion limited to 8 times, the true cut-off in the non-condensing cylinder should vary between $\frac{1}{4}$ and $\frac{1}{2}$ only.

If we make $e = \frac{3}{8}$ for a plain slide valve and adhere to 8 expansions of the steam we have $R = 5\frac{1}{3}$.

If we make the cylinders of equal size the cut-off would be $\frac{1}{8}$ and the work could all be theoretically better done by one cylinder.

The question of whether or no the lesser variations of temperatures in the use of two cylinders results in greater economy of steam could be finally set at rest by a careful series of experiments on such an engine.

For a simple engine we have the following temperatures in the one cylinder which is worked for one stroke.

Temperature of the boiler down to.

Temperature of the terminal pressure down to.

Temperature of the condenser.

in compounded cylinders.
- non-condensing
  - Temperature of boiler down to
  - Temperature of terminal pressure.
- condensing.
  - Temperature of terminal pressure down to
  - Temperature of condenser.

The same engine should be used for both experiments, care being taken to prevent the idle cylinder, which should not be disconnected, from having other than frictional resistance.

Where the net instead of the indicated horse-power is to be determined the idle cylinder must be disconnected.

The experiments should answer this question:

What ratio exists between the steam from boiler and the steam by indicator? First for the simple engine. Second for the compounded

cylinders. Also the same for heat units as shown above in tabulated results.

The engine to have the same piston speed, initial pressure and load in both cases.

We can assume that E the measure of the ultimate expansion is a controlling consideration as determining the economy in the use of steam. R is often fixed from precedent or may be determined by the limitations of the valve used.

By making the respective lengths of volume of the two cylinders (their diameters being the same) proportional to their power, the stresses will be equalized on the crank pins.

If, however, we assume, as is generally the case, that the strokes of the two cylinders are equal, that the highest safe pressure attainable will be used in the boilers, and that the ultimate expansion of the steam will not exceed 8 or 10 times, we have left for variation only the point of cut-off e of the non-condensing cylinder, the point of cut-off e_1 and the capacity of the receiver V_r and the relative capacities of the two cylinders.

If the receiver be considered it is obvious that the only result of increasing its proportions is to decrease the mean pressure of the steam against both pistons up to the point of cut-off e_1 of the condensing cylinder.

This will decrease the power of the condensing cylinder and increase the power of the non-condensing cylinder up to the point of cut-off e_1.

After steam is cut off in the non-condensing cylinder the back pressure is not so rapidly raised with a larger receiver which results in a further increase of the power of the non-condensing cylinder.

After steam is cut off in the condensing cylinder its power is in no wise affected by the size of the receiver as the pressure $P_r = \frac{eP_b}{e_1 R}$ depends on the initial pressure the ratio of the volumes of the two cylinders and their respective points of cut off.

This pressure P_r occurs when the steam is just being cut off from the condensing cylinder. Can also be written

$$P_r = \frac{P_b}{Ee_1}$$

We observe that when the capacity of the receiver is assumed very great the back pressure line of the non-condensing cylinder comes very

near being a straight line; and further, if we make e_1 equal to unity, the forward pressure line of the condensing cylinder comes near a straight line and $P_r = \frac{eP_b}{R}$

In the present case $P_r = \frac{100}{2\times 4} = 12{\cdot}5$ pounds per square inch.

We then would have for formula (7) giving, with rude approximation, the power of non-condensing cylinder.

$$V_n \left\{ eP_b \left(1 \cdot + \text{nat. log.} \frac{1}{e}\right) - P_b k - (1-k)\frac{eP_b}{R} \right\}$$

$$= 2 \left\{ 84{\cdot}7 - 10 - 11{\cdot}2 \right\} = 127.$$

and for formula (8) giving power of condensing cylinder.

$$V_c \left\{ (1-k)\left[\frac{eP_b}{R} - B\right] \right\} = 8 \left\{ 0{\cdot}9\,(12\tfrac{1}{2} - 3) \right\} = 68{\cdot}40$$

If we wish, having assumed a certain ultimate expansion E and ratio of volumes of cylinder R to determine at what point the condensing cylinder must cut off in order to render the work for the steam or gas a maximum we must so arrange that the terminal pressure eP_b shall equal the pressure of the steam in the receiver at the moment of its admission, this would require

$$\frac{P_b}{Ee_1} = \frac{eP_b\,(kV_n + V_r)}{(1 - e_1 + k)\,V_n + V_r}$$

With a fixed volume of receiver we have

$$e_1 = \frac{(1+k)V_n + V_r}{V_n + Ee\,[kV_n + V_r]} \qquad (12)$$

Which would give for the example first taken

$e_1 = 0{\cdot}47$ it has been assumed at $\frac{1}{2}$,

which probably would be near enough, if we had no clearance in the condensing cylinder, any other point, be it earlier or later, would result in diminished total power from the engine.

If the clearance in the condensing cylinder be considerable, its opening will immediately result in a disturbance of the gradual downward expansion, so that in this case we had better write, neglecting the back pressure, B,

$$e_1 = \frac{(1+k)\,V_n + V_r}{V_n + Ee\,[k\,V_n + k_1\,V_c + V_r]} \qquad (13)$$

which would give for the example taken $e_1 = 0{\cdot}32$.

This point should be particularly noted as showing how great a loss of power can occur from large clearances in compound engines.

Fixing the point of cut-off $e_1 = \frac{1}{2}$ we have from eq. (13)

$$V_r = \frac{e_1[\,V_n Ee(k\,V_n + k_1\,V_c)](1+k)\,V_n}{1 - Ee\,e_1} \qquad (14)$$

or $V_r = -1{\cdot}2$ which is impossible.

That is to say the pressure of a receiver is always productive of a loss where two cylinders are worked together, regardless of its influence on the cut-off of the condensing cylinder, and it is entirely unnecessary when cranks are together, or 180 degrees apart.

Unfortunately we cannot suppress the clearances altogether, and therefore from (13) we have, assuming $V_r = o$,

$$e_1 = \frac{(1+k)\,V_n}{V_n + Ee[k\,V_n + k_1\,V_c]}, \qquad (15)$$

This would give, in the example, to cover the clearances alone.

$$e_1 = {\cdot}36.$$

There is nothing wonderful, nor does it involve any new principle to prove, experimentally, that an early cut-off in the condensing cylinder will obtain increase of work from a given quantity of steam or gas.

V_r will represent the volume of the connecting pipes, and require the use of formula (13) in actual practice.

Cranks of compound engines are placed at angles less than 180°, for convenience of handling engines which have no fly-wheel, or which have to be stopped and started, or reversed; this procedure requires the presence of a receiver or compression space, and converts the distances of the pistons into trigonometric functions, relatively to each other, but in no wise alters the principles involved.

The assumption of a receiver, and of exaggerated clearances, in the present case, was made with a view to future use in the discussion of cranks at right angles,* and also to show clearly why they are hurtful.

---

* The writer hopes to discuss this case at length and with practical applications in the near future.

Perhaps a resumé of the method of procedure in proportioning compound engines, in the present case, may be useful.

The first point fixed upon is the number of ultimate expansions E, and this should be adhered to as a controlling consideration.

The second is to fix upon the ratio R of the volumes of the two cylinders, unless their powers must be equalized.

$$R = Ee.$$

We can then assume R and fix e, the point of cut-off in the non-condensing cylinder, or we can assume e and fix R from it.

$$R = \frac{V_c}{V_n},$$

The third is having reduced the receiver and clearances as much as is possible to fix e_1 from formula (13).

$$e_1 = \frac{(1+k)V_n + V_r}{V_n + R[kV_n + k_1V_c + V_r]}.$$

This will prevent a drop at the beginning of the stroke of the condensing cylinder, and the consequent loss of efficiency of the steam or gas.

It will be seen that e_1 would be unity were it not for the clearances and receiver.

The fourth is to calculate the relative powers of the two cylinders with these values from formulas (7) and (8).

The fifth is, when desired, to equalize the power of the cylinders for equal strokes, while still preserving the ultimate expansions E, the same, and without permitting a drop in the pressure from the terminal non-condensing to the initial condensing cylinder.

The substitution of the value of e_1, given above, in equations (7) and (8), and equating them, would be the regular mathematical method, but this is impossible because of the complicated form of these transcendental equations. We can, however, derive a first approximation in the following manner:

Assume $V_r = 0$, $k = 0$, $k_1 = 0$, $B = 0$, and therefore $e_1 = 1$.

Equate equations (7) and (8), under these assumptions, we have then the following criterion in order to equalize the power of the cylinders.

$$\frac{2R}{R-1} = \frac{\log. 2{\cdot}7183\,E}{\log. R}, \text{ and for } E = 8 = \frac{1{\cdot}337380}{\log. R} \qquad (16)$$

Which must be fulfilled.

Let $R = 4$	we have	$1{\cdot}14 = 2{\cdot} +$.
Let $R = 3$		$-3 = 2{\cdot}82$.
Let $R = 2{\cdot}9$		$3{\cdot}05 = 2{\cdot}90$.
Let $R = 2{\cdot}8$		$3{\cdot}11 = 3{\cdot}$
Let $R = 2{\cdot}7$		$3{\cdot}18 = 3{\cdot}10$.
Let $R = 2{\cdot}6$		$3{\cdot}25 = 3{\cdot}22$.
Let $R = 2{\cdot}5$		$3{\cdot}33 = 3{\cdot}35$.

That is to say, under these assumptions, R lies between 2·5 and 2·6.

$$\text{We have } e = \frac{R}{E} = \frac{2\frac{1}{2}}{8} = \frac{5}{16} \text{ of the stroke.}$$

In order that the quantity of steam used per stroke shall be the same as in the examples already solved, we must have $eV_2 = 1$ in the first case $= \frac{5}{16} V_2$. Therefore, $V_2 = 3{\cdot}\frac{1}{5}$, and $V_0 = RV_2 = 8$ as before. Let $V_1 = 1$,

$$e_1 = \frac{3{\cdot}52 + 1}{3{\cdot}2 + 2{\cdot}5[1{\cdot}12 + 1]} = 0{\cdot}53. \quad \text{See eq. (13).}$$

$$P_1 = \frac{eP_0}{e_1 R} = 23{\cdot}5 \text{ lbs.}$$

Substituting in formulas (7) and (8) as before, we have, leaving clearances the same.

For the non-condensing cylinder $3{\cdot}2\{67{\cdot}8 - 10 - 12{\cdot}00 - 7{\cdot}79\} = 121{\cdot}6$

and

For the condensing cylinder $8\{12{\cdot}00 + 7{\cdot}76 - 2{\cdot}7\} = 136{\cdot}5$.

Had there been no back pressure B, and no clearances or receiver, the cylinders would have balanced, as it is the ratio R is still somewhat too great. The short time spent in obtaining these results tentatively is well spent, and costs nothing when compared with the inconvenience and loss that may arise, when it is for any reason desirable to make the powers of the cylinders equal. Another approximation will be sufficient provided it is not deemed that losses in the non-condensing cylinder and passages will reduce the power of the condensing cylinder sufficiently when steam is used.

When these points have been covered, we must determine the size of the non-condensing cylinder for the required horse-power.

Equation (9) gives us for the work done during one stroke,

$$33{\cdot}000\,\frac{(HP)}{N}$$

all of which quantities are predetermined by the designer. If therefore we let V_n equal the product of the stroke, plus clearance in feet by the area of the piston in square inches, we have

$$V_n = AL.$$

The mean effective pressure P, we have from eq. (7).

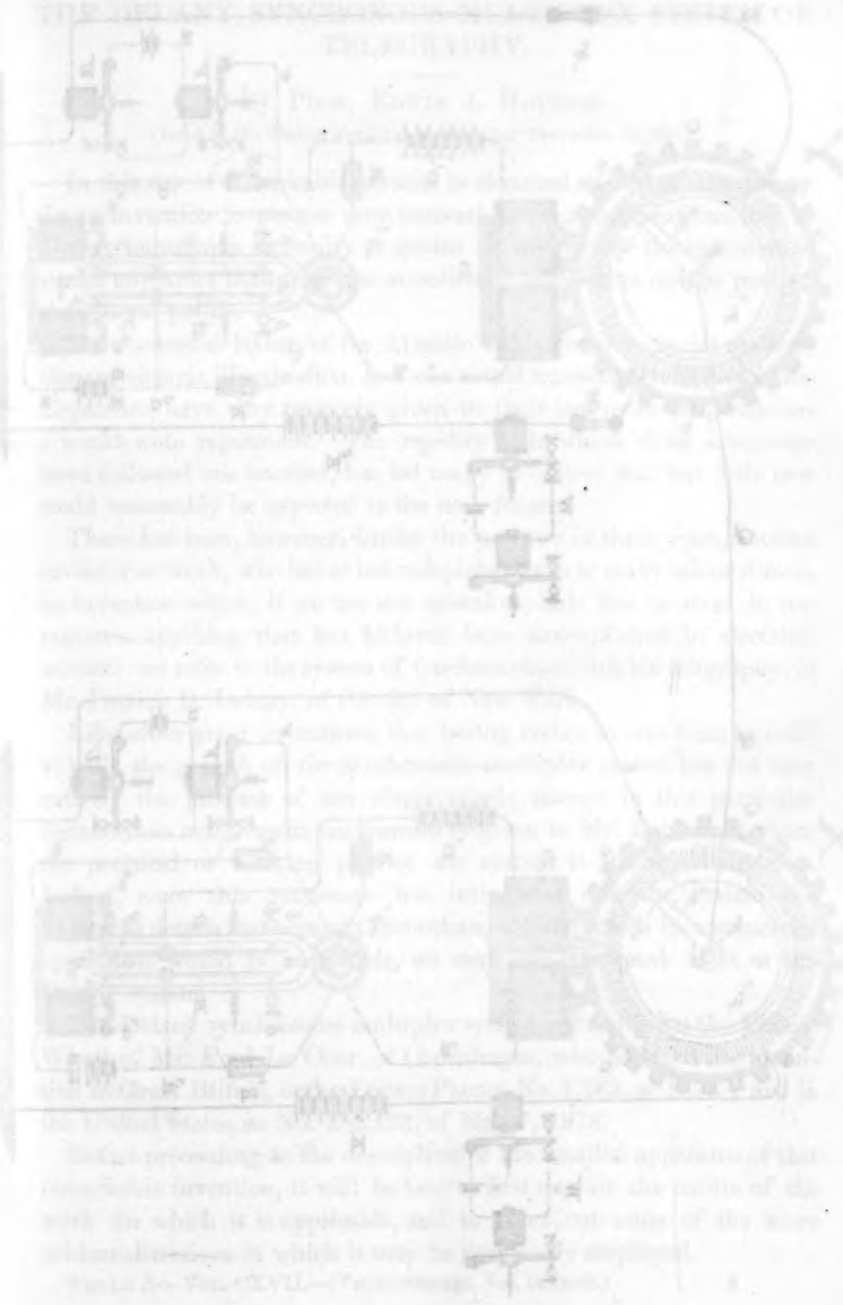
Fix the stroke in feet and we have the area of the piston in sq. inches.

$$A = \frac{33{\cdot}000(HP)}{PLN}$$

It is in improved methods of study and experiment that we must hope for advancement, rather than in the piling up of chaotic masses of more or less accurate, and almost always incomplete experimental work, only valuable for commercial purposes. One series of experiments on a compound engine, modelled after the method adopted by Mr. Hill, and carried out with equal care and skill, will give us a better basis than we have as yet for comparison with theoretical results, which we must use to guide us, knowing them not to be precise, but feeling them far more accurate than attempted generalizations from data which are in no wise comparable.

Philadelphia, November 20, 1883.

Cannons of Silk and Steel.—A German inventor proposes to wrap a steel tube with silk until a diameter is attained corresponding with the ballistic power which is required for the cannon. For any given diameter, silk possesses a tenacity as great as that of the best tempered steel, and has the advantage of a superior elasticity. After the tube has been bored, it is centred upon a lathe which turns with a great angular velocity. Above and parallel with the tube are arranged a number of spools of silk, which covers the surface in the form of a helix, by means of guides, without leaving any space between the threads. When the desired thickness has been obtained, the silk is coated with gutta-percha or hardened caoutchouc, in order to preserve it from air and dampness. The silk being a bad conductor of heat, the gun can be fired very often without getting hot, and it can be more easily managed, since its weight is only one-third as great as if it were all of steel.—*Les Mondes*, April 21, 1883. C.



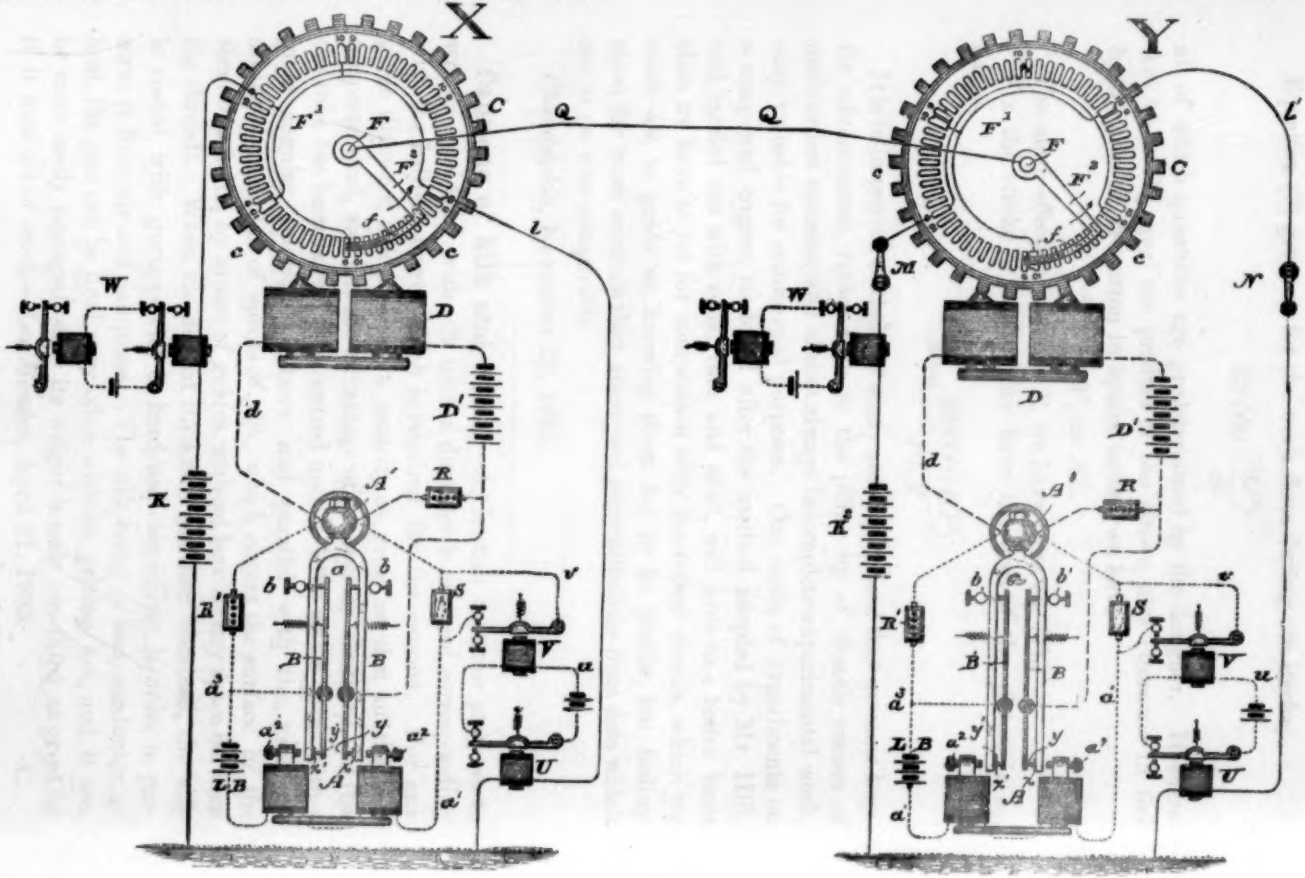


Fig. 1.

THE DELANY SYNCRONOUS-MULTIPLEX SYSTEM OF TELEGRAPHY.

By Prof. Edwin J. Houston.

[Read at the Stated Meeting, Wednesday, December 19, 1883.]

In this day of remarkable advance in electrical science, it is necessary for an invention to possess very unusual practical applications, and to display uncommon ingenuity or genius on the part of the inventor, to attract any more than transient attention or admiration on the part of the general public.

The successful laying of the Atlantic Cable, the commercial applications of electric illumination, and the actual transmission of telephonic dispatches, have very properly given to their inventors or promotors a world-wide reputation. The rapidity with which these inventions have followed one another, has led many to believe that but little new could reasonably be expected in the near future.

There has been, however, during the past two or three years, another inventor at work, who has at last completed, even to many minor details, an invention which, if we are not mistaken, bids fair to rival in importance anything that has hitherto been accomplished in electrical science; we refer to the system of synchronous-multiplex telegraphy, of Mr. Patrick B. Delany, of the city of New York.

Like other great inventions, that belong rather to eras than to individuals, the growth of the synchronous-multiplex system has not been entirely the product of any single mind; though in this particular instance, too much credit can scarcely be given to Mr. Delany, to whom the practical or working part of the system, is almost wholly due. Indeed, since this gentleman has introduced into the system the numerous details and separate inventions, without which its commercial application would be impossible, we may correctly speak of it as the Delany system.

The Delany synchronous-multiplex system is founded on the Phonic Wheel of Mr. Poul La Cour, of Copenhagen, who patented his invention in Great Britain, under Letters Patent, No. 1,983, of 1878,; and in the United States, as No. 203,423, of May 7, 1878.

Before proceeding to the description of the detailed apparatus of this remarkable invention, it will be best to first explain the nature of the work for which it is applicable, and to point out some of the more evident directions in which it may be practically employed.

The most evident commercial application of this system is its use for transmitting simultaneously, over a single wire, a great number of telegraphic dispatches, either in the same or in opposite directions.

Before the invention of the synchronous-multiplex system, the greatest number of messages that could be transmitted simultaneously over a single wire, as in the well-known quadruplex system, was four; and in this case the four messages were of necessity, sent in opposite directions; viz., two in one direction, and the remaining two in the opposite direction. In the synchronous-multiplex system, not only is the number of messages that can be transmitted greatly increased, but all such messages can be transmitted in one and the same direction; or any desired number sent in opposite directions. The great commercial importance of this feature of the invention will be at once recognized.

It may not be out of place to mention in this connection, as a confirmation of the importance of any system that will permit the simultaneous transmission of more than a single dispatch over the same wire, that it is a well-attested fact that the Western Union Telegraph Company has been enabled, to a very great extent, to practically control the telegraph business of the United States, by reason of its owning or controlling the only method heretofore known for successfully accomplishing this object.

Though we have mentioned the quadruplex as being the only system hitherto commercially employed for multiple transmission of dispatches, we have not forgotten the harmonic system of Mr. Gray. This, however, we believe, has not been commercially introduced to any considerable extent, owing to certain inherent difficulties attending its practical use.

Perhaps one of the most prominent features of the multiplex-synchronous system is its marked dissimilarity from either the quadruplex, or the harmonic systems already mentioned. The multiplex is a new departure in telegraphy, now practically realized for the first time.

As is well known to those acquainted with the principles of electromagnetic telegraphy, the quadruplex system is based on the balancing or differential method, whereby the instrument of the transmitting operator, being unaffected by the signals he transmits, is thus left open for the reception of signals sent from the distant end of the line.

The synchronous-multiplex system, on the contrary, is based on the synchronous rotation of two discs, placed one at each end of the line,

by means of which a single wire, which constitutes the line, is simultaneously connected, at both of its ends, to corresponding operating instruments, and transferred from one set of instruments to another so rapidly that the operators, either sending or receiving, cannot realize that the line has been disconnected from their instruments and given to others, because each of them will always have the line ready for use, even at the highest rate of manipulation, and will, therefore, to all practical intents and purposes, have at his disposal a private wire between himself and the operator with whom he is in communication.

It will be seen, therefore, that in the synchronous-multiplex system, although more than one operator may be spoken of as simultaneously using the line at any given time, yet in point of fact no two operators are in reality absolutely using it at the same time; but that they follow one another at such short intervals, and the line is taken from one operator and transferred to another so rapidly, that none of them can at any time tell but that he has the line alone, and that therefore it is practically open for the use of every operator just as if he alone had control of it.

There will be practically established, by the use of a single line, as many private and separate lines as there are transferences of the line from the time it is taken from the first operator, and again given back to him.

This has, as we will hereafter point out, been extended in actual practice to as many as seventy-two distinct and separate circuits, maintained and operated on a single connecting wire.

It will be readily understood that the rapidity of transmission of each telegraphic dispatch will be necessarily diminished as the number of messages, that are simultaneously transmitted, is increased. This decrease in the rate of transmission, however, is far less than might be supposed necessary, as actual experience has abundantly demonstrated. For example, with the simultaneous use of six Morse telegraphic circuits, the most rapid rate of transmission attainable by the most expert operators is practicable; and with twelve Morse circuits, a rate of transmission is practicable as rapid as that generally employed by the ordinary operator; that is, by an operator whose rate of sending would be regarded as equal to that actually employed by the greatest number. It must not be supposed, however, that the use of the multiplex-synchronous system will be limited to the simultaneous transmission of twelve separate messages on one and the same wire, since certain con-

templated improvements will, it is confidently believed, greatly increase both the rate of transmission, and the extent of division of the line.

There have been actually applied to a single line, as we have already mentioned, as many as seventy-two separate and independent circuits. In this case the Morse instruments have been replaced by the ordinary printing telegraphic instruments, so that the messages are received and recorded on paper slips, in the well-known manner as practiced in the stock printing-instruments.

Although the rate of transmission, is, in the above case, considerably decreased, yet the adoption of a printing instrument is attended with many advantages that go far towards removing the slight inconveniences that result in actual commercial use. A printing instrument, as is well known, requires no special skill on the part of the one who operates it. Any one who can spell, can transmit a telegraphic dispatch, while no operator need be on hand for its reception, since the receiving instrument is entirely under the control of the person sending the dispatch. The necessity for skilled operators, at each end of the line, is therefore in a manner entirely done away with.

Three very considerable advantages are obtained by employing printing instruments, and thus doing away with the services of skilled operators for sending and receiving the dispatches viz.; economy, secrecy and an increase in the number of messages that can be sent during any given time.

The advantages on the score of economy and secrecy are manifest. Not only is the skill of an operator required at each end of a private line employing Morse instruments, but since private messages are to be transmitted thereon, integrity, as well as skill, is a prime essential, and both of these requisites must be paid for. On private lines, maintained by the use of the synchronous-multiplex system and printing instruments, no publicity is necessary, the interested parties only, sending and receiving the dispatches.

The advantages on the score of rapidity arising from no operator being needed at the receiving station, when printing instruments are employed on a private line, lie in the fact that the line being a private one, no time is lost in waiting for some other party that may be using it, nor in calling the party for whom the dispatch is designed, or in waiting for his return, during a temporary absence.

Taking all these facts into consideration, we think it will be found in actual practice, that the decrease in the rapidity of transmission,

consequent on the simultaneous employment of seventy-two separate circuits on one and the same line, is not sufficiently great to interfere to any marked degree with its commercial applications. In point of fact, with the system as it is now actually used, the rate of transmission is quite sufficient to enable each of the seventy-two subscribers or users of the line, to transmit, during, say the six hours that elapse between 10 A. M. and 4 P. M., the business hours of the day, no less than one hundred telegraphic dispatches of the ordinary length, an amount generally in excess of actual requirements of ordinary business, and, as a rule, quite in excess of any rate of service that could be reasonably expected on, the part of any of the telegraphic companies on which the general public are now dependent.

An advantage, however, of peculiar importance to the business public generally, that is possessed by the synchronous-multiplex system alone, is the readiness with which a single wire between any two subscribers connected therewith, can be increased in its capacity to meet the growing needs for an increased extent of division, or to meet some unforseen or unexpected emergency. Thus, suppose that one subscriber has a private line placed at his disposal between any two distant cities, and is furnished with what we may term one-seventy-second of the line; should his business increase, it would be a matter of simple connection of the transmitting and receiving instruments at the ends of the line to give him increased facilities for communication by placing at his disposal the one-thirty-sixth, or the one-eighteenth, and so increase his capacity for communication twice or four times respectively. In other systems, as is well known, this would need the erection of extra lines, and would necessitate the expenditure of both time and money, so that sudden and unexpected calls for increased facilities for business, which are liable to occur in times of financial crises, or of other great public excitement, could not be met.

A peculiar feature of the synchronous-multiplex system, that is not possessed by any other known telegraphic system, and that cannot fail to commend this system to the general public, is in its absolute secrecy. Unlike other systems, its lines cannot be secretly tapped and the messages intercepted, since, an ordinary instrument placed in a break in the line, would receive, in an utterly unintelligible form, not only all the signals being transmitted at the time, but also each of the separate makes and breaks in the continuity of the line circuit, while it is successively transferred from one operator to another, and these signals would be

so transposed and altered, that even if the instrument could record them, they would be as devoid of intelligent connection, as would the type, corrrectly set for numerous messages, and afterwards dropped through successive sieves from a height to the ground. This feature of absolute secrecy of the synchronous-multiplex system will, it is believed, prove of almost inestimable advantage to a government for the secret transmission of dispatches during war, or, in fact, at any time.

The successful operation of the synchronous-multiplex system is dependent on the maintenance of the synchronous movements of the rotating discs placed at the ends of the line. We will now proceed to describe the details of the very ingenious and beautiful contrivances whereby Mr. Delany has practically created a new system of telegraphy.

Fig. 1 represents a diagrammatic plan of two distant stations, say New York and Philadelphia, or Philadelphia and Chicago, represented by *X* and *Y*, respectively, electrically connected by the single line wire *Q Q*. The connections of the detailed apparatus required at both the transmitting and receiving stations are also shown in the figure.

In the following description the author has not hesitated to freely employ the language of the various patent specifications in all cases where he has deemed it advisable so to do.

An inspection of Fig. 1, will show that the apparatus at each end of the line, at the stations *X* and *Y*, is substantially identical. A steel fork *a*, at each station, is automatically and continuously vibrated by the action of the local battery *L B*, and the electro-magnet *A*. The circuit of the local battery is marked in the drawing a^1. The cores of the magnet *A*, which may be called the vibrator magnet, are prolonged in the direction of the free ends of the vibrating fork by the regulable screws a^2 of magnetic material, in the manner shown in the figure. The object of this adjustment of the extended magnet poles is to enable the said poles to be approached towards, or withdrawn from the tines of the vibrating fork, so as to regulate with great nicety, the rate of their vibration.

Platinum contacts x, x^1, are placed on the inner faces of the tines of the fork, and make and break contact with delicate platinum contact springs y, y^1, supported by adjustable insulated arms or levers B, B^1, pivoted on the bed-plate of the apparatus. The adjustment of these levers is secured by the thumb-screws b, b^1, against which they are drawn by the action of spiral springs. By these means the platinum

contact-springs y, y^1, are readily adjusted with great delicacy and firmness to the platinum contacts x, x^1, on the tines of the fork.

The circuit of the local battery $L\,B$, which is indicated in the drawing by the fine dotted lines, runs from the positive pole of the battery, through the coils of the vibrator magnet A, to the head of the fork, and through the contacts x^1, y^1, to the insulated lever B^1, from whence it passes back to the opposite pole of the battery. In order to prevent injurious sparking of the contacts x^1 and y^1, a resistance coil, R^1, is placed in a shunt circuit around them, extending from the point a^3, to the head of the fork, and to the insulated arm B^1, as shown.

The fork being mechanically started into a vibratory motion, will automatically make and break its local circuit, and thus send impulses into the fork-magnet A, that will continuously maintain the vibrations of the fork, in a well-known manner.

These movements, it will be observed have been maintained solely by the making and breaking of the contacts x^1, and y^1.

And now for the contacts x and y, which as we have seen, are placed in connection with the opposite tine of the fork. The making and breaking of these contacts, consequent on the fork's vibration, opens and closes the circuit of another local battery in which is placed an electro-magnet D, the function of which is to maintain the continuous rotation of the transmission apparatus C.

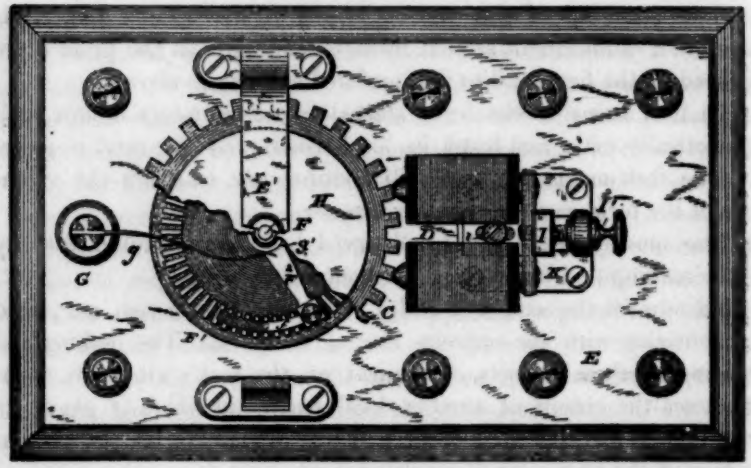
This circuit, which we will call the motor circuit, and which is indicated in the drawing by the larger dotted lines, passes from the positive pole of the motor-battery D^1, to the lever B, through the platinum contacts y and x, to the tine of the fork, to its head or support A^1, and thence through the wire d, to the coils of the motor magnet D, and back to the opposite pole of the battery. A resistance R, placed in a shunt between the head or support of the fork and the line of the lever B, prevents injurious sparking between the platinum contacts x, and y.

As the continuous vibration of the fork is automatically maintained by the local battery $L\,B$, as already explained, it will, at each vibration, make and break the contacts at x, and y, and thereby make and break the motor circuit. The alternate magnetization and demagnetization of the cores of the motor-magnet D, causes the rotation of the transmission apparatus C. The cores of the magnet D, have their faces shaped so as to conform to the circumference of the apparatus C, the teeth of which pass in close proximity to the faces of the curved magnet poles.

The motor-magnet and transmission wheel or disc *C*, provided with projections *c*, *c*, is the invention of Poul La Cour, already referred to, and is styled by him a "phonic wheel."

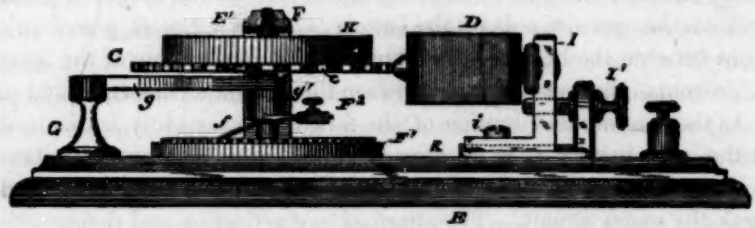
The transmission apparatus is illustrated in detail in Figs. 2 and 3. As we have already seen, it is an exact counterpart of the receiving

FIG. 2.



apparatus at the other end of the line. A base plate, *E*, provided with binding posts for electrical connections, carries a vertical rotary shaft *F*, that has its lower bearing in the bed plate, and its upper bear-

FIG. 3.



ing in a suitably supported bridge, E^1. A circular table, F^1, provided with a series of insulated contacts, is arranged symmetrically around the axis of rotation of the shaft. A radial arm, F^2, projects from the shaft, *F*, and carries at its outer extremity a socket and set screw, to which is attached a trailing contact finger, *f*. As the disc, *C*, is rotated

by the electro-magnet, *D*, the trailing contact, *f*, sweeps around the circular table, F^1, and is brought successively into contact with the insulated contact-pieces placed on the upper face of the table F^1.

The main line, *QQ*, has one of its ends connected with the trailing finger, *f*, through the radial arm, F^2, vertical shaft, *F*, contact spring-arm, *g*, and projecting post *G*. As the shaft *F* rotates, the line is therefore brought into successive electrical connection with the series of insulated contacts in the upper face of the table F^1. The toothed armature, or phonic wheel *C*, is securely keyed to the vertical shaft *F*, just above the hub g^1.

In order to equalize the speed of rotation of the apparatus, a cylindrical vase, *H*, of wood or other suitable material, filled with mercury, is attached to the face of the phonic wheel *C*, and rotates with it.

The cores of the motor magnet *D*, suitably supported by the standard *I*, can be readily adjusted towards or from the armature teeth on the phonic wheel *C* by the motion of a screw, I^1, which moves the standard, *I*, in an elongated guide slot, through which passes the screw bolt, *i*.

The cause of the synchronous rotation of the phonic wheel *C* is substantially as follows, viz.: Considering the action of a single pole of *D* when the wheel *C* is at rest, that one of its teeth or projections, *c*, that is nearest the pole of *D*, will be attracted towards it, and maintained in position nearest it, by the influence of the magnetic attraction of the pole of *D*; should, however, the phonic wheel be set into motion, with a velocity that shall cause a tooth, *c*, to pass the pole *D*, for each intermittent impulse in the battery circuit traversing the coils of *D*, the wheel will be maintained in a rotation, the speed of which will be regulated and controlled by the frequency of intermission of the battery current through the coils of *D*. That is to say, the speed of rotation of the phonic wheel *C*, and consequently the rapidity with which the successive contacts are reached by the trailing arm F^1, are regulated solely by the duration of the oscillation of the fork *a*.

FIG. 4. FIG. 5. FIG. 6.

The control which the intermission in the circuit traversing the coils of the electro-magnet *D*, exercises on the regularity of rotation of the phonic wheel *C*, will be better understood from an inspection of Figs. 4, 5 and 6.

Suppose that the central or axial line of the pole of the magnet *c*, is represented by the dash placed opposite *c* in the figure, and that *r*, indicates the centre of the phonic wheel *C*, whose direction of rotation is indicated by the arrow. Now, if during one impulse the central or axial line of one of the magnet teeth, *c*, on the phonic wheel, is moved from the point *s* to *t* it will be accelerated on its way from *s* to *c*, but retarded from *c* to *t*.

If then, as shown in Fig. 4, the acceleration and retardation are equal, the velocity of the wheel is unaffected by the impetus of the electro-magnet; but, should the wheel move slower, that is, lose in its motion, as shown in Fig. 5, then the acceleration, *s*, *c*, will increase, and the retardation, *c*, *t*, will decrease. Consequently, the electro-magnet *D*, will increase the velocity of the wheel in the same ratio that the wheel slows, or loses time.

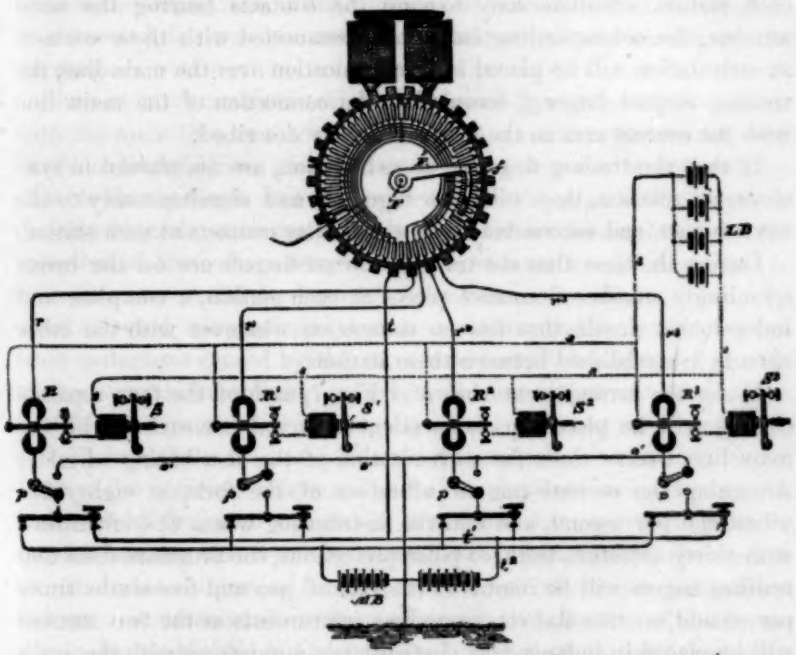
If, however, the wheel gains or increases in speed, as shown in Fig. 6, the acceleration *s*, *c*, will be decreased, and the retardation *c*, *t*, increased, so that the electro-magnet will have the opposite effect, and retard the wheel, in the same ratio that it tends to increase or go faster.

In the apparatus for transmission and reception, shown in connection with Fig. 1, which is substantially the same as that just described, the table of contacts F^1 is, for convenience of illustration, shown as placed above the armature disc *C*. In starting the disc *C*, an impulse of rotation is given to it somewhat in excess of the speed at which it will be maintained by the motor magnet, when, as the speed of rotation decreases, the armature teeth will come into proper relation with the poles of the magnet, and into the periods at which the makes and breaks occur in the circuit traversing its coils, when the disc will be continuously driven by the motor magnet. A suitable thumb piece, placed on the vertical axis F^1 serves to start the apparatus, an operation that is readily accomplished after very little practice.

Any suitable number of insulated contacts may be placed on the circular table F^1; sixty are shown in the figure. In practice these contacts are connected in accordance with the special number of circuits, which it is desired to simultaneously maintain on the same wire. In the special case shown in connection with Fig. 7, it is arranged so that four separate circuits shall be established on the same line wire. The sixty contacts are placed in six independent series, numbered from 1 to 10, consecutively. In the arrangement here shown, two of the contact pieces, in each series of ten, are connected in the same circuit, and

as there are six series, each of the circuits so connected will have twelve contacts for each rotation of the disc. An inspection of Fig. 7 will show that the 1's and the 5's in each series are all connected in one and the same circuit; the 2's and the 6's in another circuit; the 3's and the 7's in another circuit, and the 4's and the 8's in another circuit, thus providing four separate circuits in all. The contacts, therefore, from one to eight in each series, are apportioned among the four independent circuits, each of which will receive, for each revolution of the

FIG. 7.



trailing finger, twelve contacts and twelve electrical impulses, as will be afterwards described.

The detailed mechanism by means of which the separate and independent circuits so obtained are utilized for the transmission and reception of messages is shown in connection with Fig. 7. R, R^1, R^2 and R^3 are polarized relays, the function of which will be afterwards explained. S, S^1, S^2 and S^3 are ordinary Morse sounders, although in the practice of this invention some improvement has been introduced in connection with the instrument, the connections with the main and the local batteries, MB and LB, are clearly shown in the figure.

Suppose that the central or axial line of the pole of the magnet c, is represented by the dash placed opposite c in the figure, and that r, indicates the centre of the phonic wheel C, whose direction of rotation is indicated by the arrow. Now, if during one impulse the central or axial line of one of the magnet teeth, c, on the phonic wheel, is moved from the point s to t it will be accelerated on its way from s to c, but retarded from c to t.

If then, as shown in Fig. 4, the acceleration and retardation are equal, the velocity of the wheel is unaffected by the impetus of the electro-magnet; but, should the wheel move slower, that is, lose in its motion, as shown in Fig. 5, then the acceleration, s, c, will increase, and the retardation, c, t, will decrease. Consequently, the electro-magnet D, will increase the velocity of the wheel in the same ratio that the wheel slows, or loses time.

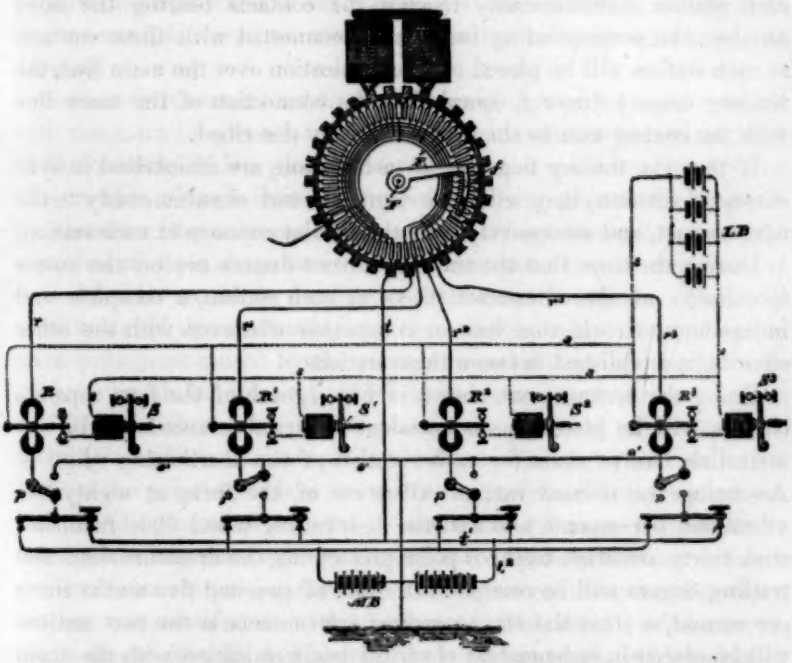
If, however, the wheel gains or increases in speed, as shown in Fig. 6, the acceleration s, c, will be decreased, and the retardation c, t, increased, so that the electro-magnet will have the opposite effect, and retard the wheel, in the same ratio that it tends to increase or go faster.

In the apparatus for transmission and reception, shown in connection with Fig. 1, which is substantially the same as that just described, the table of contacts F^1 is, for convenience of illustration, shown as placed above the armature disc C. In starting the disc C, an impulse of rotation is given to it somewhat in excess of the speed at which it will be maintained by the motor magnet, when, as the speed of rotation decreases, the armature teeth will come into proper relation with the poles of the magnet, and into the periods at which the makes and breaks occur in the circuit traversing its coils, when the disc will be continuously driven by the motor magnet. A suitable thumb piece, placed on the vertical axis F^1 serves to start the apparatus, an operation that is readily accomplished after very little practice.

Any suitable number of insulated contacts may be placed on the circular table F^1; sixty are shown in the figure. In practice these contacts are connected in accordance with the special number of circuits, which it is desired to simultaneously maintain on the same wire. In the special case shown in connection with Fig. 7, it is arranged so that four separate circuits shall be established on the same line wire. The sixty contacts are placed in six independent series, numbered from 1 to 10, consecutively. In the arrangement here shown, two of the contact pieces, in each series of ten, are connected in the same circuit, and

as there are six series, each of the circuits so connected will have twelve contacts for each rotation of the disc. An inspection of Fig. 7 will show that the 1's and the 5's in each series are all connected in one and the same circuit; the 2's and the 6's in another circuit; the 3's and the 7's in another circuit, and the 4's and the 8's in another circuit, thus providing four separate circuits in all. The contacts, therefore, from one to eight in each series, are apportioned among the four independent circuits, each of which will receive, for each revolution of the

FIG. 7.



trailing finger, twelve contacts and twelve electrical impulses, as will be afterwards described.

The detailed mechanism by means of which the separate and independent circuits so obtained are utilized for the transmission and reception of messages is shown in connection with Fig. 7. R, R^1, R^2 and R^3 are polarized relays, the function of which will be afterwards explained. S, S^1, S^2 and S^3 are ordinary Morse sounders, although in the practice of this invention some improvement has been introduced in connection with the instrument, the connections with the main and the local batteries, *MB* and *LB*, are clearly shown in the figure.

It will be noticed that the relay R, is connected by the wire r, with the contacts 1 and 5; R^1 is connected by r^1, with the contacts 2 and 6; R^2 by the wire r^2, with the contacts 3 and 7, and R^3 by the wire r^3, with the contacts 4 and 8. Similar instruments and circuits are placed at each end of the line.

Without further describing the operation of the instruments shown in Fig. 7, it need only now be borne in mind that the corresponding relays at the distant stations are connected with the correspondingly numbered contacts. When, therefore, the trailing contact finger at each station simultaneously touches the contacts bearing the same number, the corresponding instruments connected with these contacts at each station will be placed in communication over the main line, the trailing contact finger f, completing the connection of the main line with the contact arm in the manner already described.

If then the trailing fingers f, at each station, are maintained in synchronous rotation, they will pass regularly and simultaneously to the next contact, and successively over the similar contacts at each station.

During the time that the trailing contact fingers are on the correspondingly numbered contact pieces at each station, a complete and independent circuit, that has no connection whatever with the other circuits, is established between these stations.

Under the arrangement shown in Fig. 7, each of the four separate circuits will be placed in independent electrical connection with the main line, twelve times for each rotation of the distributing wheel C. Assuming the normal rate of vibration of the fork, at eighty-five vibrations per second, and that the distributing wheel C, is furnished with thirty armature teeth, or polar projections, the armature discs and trailing fingers will be rotated at the rate of two and five-sixths times per second, so that the corresponding instruments at the two stations will be placed in independent electrical communication with the main line, thirty-four times each second. This number of contacts per second will give to each set of operators a practically unbroken circuit, so that the operators at any two connected stations may communicate with each other, in either direction, as if they had a separate and independent line devoted entirely to their exclusive use.

We will now describe, in greater detail, the method adopted for transmitting and receiving the messages over any or all of the four circuits so provided. An inspection of Fig. 7 shows the relays, R, R^1, R^2 and R^3, connected with the series of contacts as described,

and the circuit completed from each relay, either to the ground through the line o^1, when the switches p, are placed as at R^1, and R^3, on their upper contacts, when the line is ready for receiving; or in connection with their lower contacts, as at R, and R^2, when the line is ready for transmitting.

The main battery *MB*, preferably split and grounded in the middle, has its positive pole connected with the back stops of the keys, and its negative pole with their front stops. The act of transmitting, therefore, sends into the line impulses of opposite polarity, and therefore permits the employment of the polarized relays. The local battery *L B*, is connected in multiple arc, in the manner clearly shown in the drawing.

Since each operator's circuit is made up of numerous rapid contacts with the main line, at the rate of thirty-four contacts per second, each of the ordinary Morse characters sent into the main line, is made up of more than a single contact, proportioned in number to the length of the character, the ordinary Morse relay could not be employed for the reception of these characters, since the numerous breaks comprised in each character would be recorded by the armature of the relay. In order to avoid this confusion, and to make the relays respond not to mere pulsations caused by the successive makes and breaks, but only to the reversals in polarity, caused by the connection of the split battery *M, B*, with the transmitting keys, the polarized relays *R*, R^1 R^2 and R^3, have been used in place of ordinary relays, so that the armatures of the polarized relays remain in the position that the last current has placed them, until reversal of the current changes their position, notwithstanding that the finer vibartions comprised in these reversals are continuously passing through the magnet of the polarized relay, but are not manifested on the armature. This feature of the invention is due to Mr. E. A. Calahan, the inventor of the gold and stock printing telegraph, and also the inventor of the American District Telegraph System, and who has been associated with Mr. Delany from the commencement of his investigations on the subject, and whose ability and great mechanical skill have very materially aided the full development of the system.

The prime essential for the successful application of the preceding system is undoubtedly the maintenance of the synchronous movements of the trailing arms over the contact pieces on the table F^1. This Mr. Delany has effected by an invention of marvelous beauty and ingenuity,

which is entirely automatic in its operation, and is so successful in practice, that the synchronism can be so perfectly maintained for days continuously without one instrument varying from the other the six-hundredth part of a second during that time. We will now proceed to an explanation of the comparatively simple means by which this practically absolute synchronism is maintained.

It has been shown, in connection with the description of the operation of the transmitting wheel, that its rate of motion is absolutely controlled by the rate of vibration of the fork, by means of which the successive impulses of the battery current through the motor-magnet are regulated.

Now it has been tried, but unsuccessfully, to obtain this synchronism by the mere mechanical adjustments of two forks, one at each end of the line; the forks being delicately tuned to exact unison with one another.

The many circumstances which produce slight variations in the rate of vibrations of a fork, have rendered it impossible to maintain, even in the same room, synchronism between two forks for more than a few minutes at a time, and this has only been possible by the most careful attention to the adjustments of the same. At distant stations, where the mere differences of temperature alone would, of necessity, produce sensible variations in the rates of motion of the two forks, the maintenance of even approximate synchronism would be practically impossible.

Mr. Delaney has completely overcome this hitherto insuperable obstacle to the successful adoption of any synchronous-multiplex system, by the happy invention of correcting impulses, that are automatically sent over the main line from one instrument to another, at such times only as the distant instrument is slightly in advance or behind the other instrument. These correcting impulses, that are thrown into the line only when needed, and of the necessity for which the instruments themselves, so to speak, are constituted the judges, are utilized for the purpose of slightly increasing or decreasing the rate of vibration of the distant fork, and consequently, the rate of rotation for the trailing arm at the distant station.

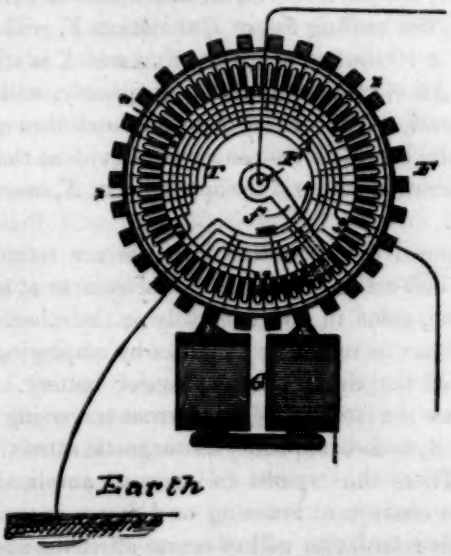
The manner it which these impulses are obtained when needed is as follows: It was probably remarked by the reader, that in speaking of the contacts in the plate F^1, no mention was made of the 9's and the 10's in any of the series, as having connection with any of the tele-

graphic instruments or circuits. It is the function of these contacts to maintain the synchronism of the apparatus.

Referring again to Fig. 1, it will be noticed that at one of the stations, as *X*, three of the 9's, that are the furthest removed from one another, that is three that are 120° distant from each other, are connected together, and to a battery *K*, one pole of which is connected to the ground; and that three of the 10's, that are likewise furthest removed from one another, are connected together and to a line *l*, leading to the correcting and regulating devices, which we will afterwards describe. The remaining three intermediate 9's and 10's are left open, that is, are not connected with any circuit.

At the other station *Y*, the 9's, corresponding with those connected with the battery at *X*, are left unconnected or open, while the alternate 9's, are connected with the battery K^2, one end of which is grounded,

FIG. 8.



while the 10's at *Y*, which are connected with one another and with the correcting devices through the line l^1, correspond with those which are unconnected with the station *X*, the remaining 10's, at *Y*, being unconnected at both stations; the three 10's, which are connected with the correcting devices through the lines *l*, and l^1, respectively, are extended or built out towards the adjoining 9's, that are unconnected with any circuit.

In order to provide room on the table F^1, for the expanded or extended 10's, without disturbing the symmetrical arrangement of the remaining contacts, the plates or contacts provided for the static discharge of the line, and which an inspection of Fig. 8, will show as located between each of the successive contacts of the circular table F^1, are omitted, and their place occupied by the extension of the expanded 10's, so that the space between the expanded 10's and the 9's which precede them, is the same as the spaces between the remaining contacts. Since the 9's preceding the extended 10's, and corresponding in position to the battery-connected 9's are open or disconnected, and since the static discharge plate between the 9's and the 10's at the distant end is retained, no bad results are experienced.

As long as the trailing contact-fingers are moving synchronously at both stations, that is, as long as they rest on correspondingly numbered contacts at the same moment, no occasion will exist for the correction of either apparatus; should, however, the instrument at Y, run a trifle faster than that at X, the trailing finger f, at station Y, will touch the extended side of a 10 contact, while the finger at X is still on a battery connected 9. An electrical impulse, consequently, will flow from the battery K, at station X, over the main line, and through the contact 10, at Y, and the line l^1, to the connecting device at that station.

A similar operation occurs if the apparatus at X, moves a trifle faster than that at Y.

As thus arranged the correcting impulses are retarding ones, since they are called into action only when the instrument at one or the other ends of the line, gains in speed slightly on the other. The inventor causes them to act as retarding impulses by employing them to cut a resistance out of the circuit of the vibrator battery. The effect of this is to increase the strength of the current traversing the coils of the electro-magnet A, and consequently its magnetic attraction for the tines of the fork. There thus results an increased amplitude of the forks' vibration, and a consequent lowering or decrease in the rapidity of its vibration. This retardation will of course affect the speed with which the transmission wheel is rotated, and consequently retard the rotation of the trailing finger.

The local circuit of the vibrator is shown in Fig. 1 as working generally through the adjustable resistances S. When, however, the apparatus at one station runs slightly in advance of that at the other sta-

tion, and a correcting impulse is consequently received through the main line and the line, l or l^1, the relay U, placed in that line, is energized, and its armature drawn from its back stop, thus breaking the local circuit u, and permitting the armature of a second electro-magnet V, to rapidly pass to its back stop, and thus complete a shunt circuit v, around the resistance S, so as to cut it out of the vibrator circuit. The consequent increase in the current strength of the vibrator circuit that is thus momentarily produced, momentarily retards the rate of vibration of the fork, and consequently slows the rotation of the trailing finger, and causes it to drop back on its proper contact. The operation is the same at both stations.

Whenever the operator at either station hears the stroke of the relay V, he knows that a correcting impulse has been received. By placing a relay and sounder W, in the circuit of the correcting battery, at each station, between the 9 contacts and the ground, he can also tell when a correcting impulse has been sent out. No difficulty will be experienced, therefore, in ascertaining which of the instruments is slightly in advance of the other, but as long as any ticks or sounds are heard on the instruments on the correcting circuits, the instruments will be found to be in synchronism, since the variations possible are confined to a limit not exceeding one-fifth of the width of any regular segment.

The apparatus is readily started by starting the fork and rotating the vertical shaft F, and the adjustment of the two apparatus is completed at the other station, Y. At that station the operator also starts his apparatus and closes the switches at M, and N. By the means already described the operator at Y, can tell which apparatus is running the faster, and he then proceeds to adjust his own apparatus, until he is aware of the synchronism of the two, by the tell-tale strokes at V, and W. It is found convenient in practice to make the resistance at S, in the shape of a box of resistances, so as to readily vary the amount of resistance normally included in the local circuit.

A very important and beautiful feature of this invention is found in the manner in which the correcting impulses are rendered effective when the relay U, leaves its back stop, as the corrections are thereby rendered practically instantaneous; whereas, if they were not made effective until the armature of the relay had been drawn to its front stop, the action of the correcting device, would be sluggish. The adjustment of the armature of the relay U, is very delicate, and it therefore, responds immediately to any correcting impulse; so, too, the

spring of the relay, *V*, is of sufficiently high tension to enable its armature to move almost instantaneously to its back stop.

Should the trailing arm at one station be moving more rapidly than that at the other station, it must soon overtake the trailing arm at the other station and bring them both into such relation to the battery connected 9's, and the extended correcting 10's, that the correcting impulses will thereafter maintain them in practical synchronism.

Should the main line between the two stations be accidentally broken, the synchronism would of course be destroyed, but on connecting it again, the instruments would of themselves, within two or three minutes at the most, again come into synchronism without the intervention of the operators.

The correcting impulses, we have described are retarding ones, and are only called into play, when one instrument runs faster than the other. Mr. Delaney has slightly modified his apparatus. so as to make the correcting impulses accelerating ones, that are only called into play when one instrument runs slower than the other.

In this connection it may be well to state that numerous devices by means of which synchronism can be obtained in connection with substantially the apparatus before described, have been discovered by Mr. Delany, and are fully protected.

We have described four sets of independent circuits simultaneously established on the same line. It is evident, however, that by increasing the speed of rotation, fewer contacts during a single rotation will suffice for the practical operation of the ordinary Morse circuits, or by increasing the number of contacts in the circle, a much greater number of circuits may be obtained, so that the subdivision of the line into a greater number of circuits may be effected, without diminishing the speed of working.

An essential feature of the invention, without which it cannot be practically operated for long distances, consists in separate contacts, as shown in Fig. 8, placed between the contacts on the table F^1, at each station, and connected together to the ground, so that the line, being put to the ground before each completion of the circuits, will be freed from the greater or less static charge, which is very apt to be present in all lines of any considerable length.

The synchronous-multiplex system, though as we have seen is somewhat complicated in its apparatus, is far simpler in its operation, and requires far less delicate adjustments than are essential in the quadru-

plex system. The difference between the two in this respect will the better appear, when it is known, that in the quadruplex system a change of electrical condition, equivalent to an increase in the length of the circuit of ten miles, is sufficient to throw it out of balance, and thus stop all communication; while in the synchronus-multiplex system, a change equivalent to five hundred miles may be instantly thrown on the synchronously operated wire, without destroying the synchronous rotation of the trailing arms, or interrupting the various circuits.

The possibilities that suggest themselves as naturally resulting from the solution that Mr. Delany has made of the problem of obtaining and maintaining, at distant stations, practically absolute synchronism, are, indeed, bewildering, and justly entitle this gentleman to a place among the world's great inventors.

Central High School, Philadelphia.
November 29, 1883.

Preservation of Paintings in the Parisian Opera House.—The paintings of M. Baudry, in the foyer of the Grand Opera House, have been greatly injured and almost obliterated by the smoke which escapes from the gas burners. The trouble might have been avoided if the arrangements of the lights had been more carefully studied. Each chandelier is composed of four clusters, each cluster having eight fan-shaped burners arranged symmetrically around the central support, and with a crown of eighteen jets placed above these burners. In consequence of this arrangement the strong ascending current of air, produced by the combustion in the lower clusters, agitates the jets of the upper crown and renders the combustion incomplete. The smoke which is thus produced deposits a thick layer of lampblack upon the paintings. M. Decaux, the subdirector of the dye-works at the Gobelins, proposes to change the arrangement of the chandeliers, so as to produce a complete combustion of the gas and rapidly remove the air charged with the products of combustion, of which the sulphurous acid is especially injurious to colors. The employment of the electric arc is impossible, because it fades the colors as effectually as sunlight. The incandescent electric light, as hitherto produced, has a tint which is too orange to give a good effect.—*Soc. d'Encour.*, Oct. 27, 1882.

Upper Limit of Audible Sounds.—E. Pauchon has tested the hypothesis of many physicists, that the upper limit of audibility of any given ear varies with the intensity of the sound. Using a Cagniard-Latour siren, he found that when the pressure of the steam, in the interior of the box, varies from 0·5 to 1·5 atmospheres, the limit of perceptibility corresponds to sounds which are comprised between 48,000 and 60,000 vibrations per second. On increasing the steam pressure to 2·5 atm., giving the discs a rotation of 600 turns per second, he could hear the sound of 72,000 vibrations, which was the sharpest that he was able to produce. He then vibrated, longitudinally, metallic rods fixed at one extremity, by rubbing them with rosined cloth. He found that the length of the rod which gives the limiting sound is, for any given metal, independent of the diameter. For steel, copper, and silver, the lengths are sensibly proportional to the velocity of sound in those metals. By using an ear trumpet the limit of perceptibility is slightly increased. If the rods are excited with different substances, such as rosin, turpentine, alcohol, ether, the limiting length changes and may vary from one to two. The sound which has ceased to be perceptible by the ear still acts powerfully upon a sensitive flame.—*Comptes Rendus*, April 9, 1883. C.

Protection from Boiler Explosions.—It has been noticed that boiler explosions are especially frequent in the morning. Take, for example, an engine which works during the day with steam at 6 atmospheres. The workmen leave the factory at 7 P. M.; about six o'clock the fireman reduces his fires and leaves the boiler with the gauge at 4 atmospheres. On returning the next morning, at 5h. 30m., he generally finds the gauge at 1·5 or 2 atm., with a fine water level. He profits by the reserved heat, which represents a certain expenditure of fuel; as an economist he utilizes it and drives his fires, to be ready for the return of the workmen, without suspecting the dangers concealed in the water which has been boiling all night. He does not feed his boilers, because they are at a good level. In other words, he prepares, unconsciously, the conditions which are most favorable to superheating and a consequent sudden and terrible explosion, which will be attributed to some mysterious and unknown cause. Trèves recommends that, before starting the fires in the morning, the fireman should restore to the water the air which it needs, by injecting it, with the aid of pumps and suitable tubes, into the lower portions of

the boiler. As soon as the gauge of the pump indicates a pressure which is superior to that of the remaining steam, all danger is removed; the fires can then be driven, ebullition goes on normally and explosions become materially impossible.—*Comp. Rend.*, Ap. 9, 1883.

Mechanical and Physical Units.—The use of the kilogramme as a unit of weight has been so generally adopted that few would attempt to displace it, notwithstanding the inconvenience which results from the variations of weight with the place of the observer. A. Ledieu proposes to give it a fixed value by dividing it, in every calculation, by the ratio of the gravitating acceleration g of the place of observation to the gravitating acceleration g' of a place agreed upon, the pole for example. This mode of operation would take from the unit every characteristic of special nationality and would reduce every problem to the hypothesis of a dynamometer, with unalterable springs, gauged at the pole; moreover masses and forces would be subjected to an identical correction. The ratio of g to g' varies from 1 to ·9949, for corresponding elevations above the level of the sea. If this ratio is overlooked, in experiments which are performed in different countries, errors of comparison may arise which are greater than the errors inherent in the copies of the standard of weight. Ledieu also makes valuable suggestions in regard to the units of time and space.—*Comp. Rendus*, April 9, 1883. C.

Color of Precious Stones.—Lt. Col. W. A. Ross, 1871, tried to obtain a blue color by dissolving pure alumina in a pearl of borax; after a half-day's work he obtained a very pale-blue pearl, hard enough to scratch glass. This experiment led him to think that the blue color of sapphire is due to its 98 per cent of alumina, and not to the traces of any metallic oxide. In the following year experiments with lime which had been freshly calcined and with hydrated lime, showed a remarkable influence of the water upon the coloring, both of the flame and of the pearl. In 1873 he found that by dissolving pure alumina, under the blow-pipe, in a pearl of boric acid which had been opalized by means of platinum, and adding a small proportion of hydrate of potassium, he obtained a bluish pearl, much more rapidly and easily than by his first experiment. Some years later he bought, in London, a little American wavellite. On treating the powder of this mineral, under the blow-pipe, in an opalized or hydrated pearl of borax, with a

little hydrate of potash, he was astonished to see that his pearl became purple, then blue, and finally of a brilliant green. Subsequent experiments satisfied him that although phosphoric acid has not been discovered in sapphire or in lapis lazuli, it may have contributed to their coloring; for lazulite, which is similarly blue, is essentially a phosphate of aluminum, and pure phosphoric acid is well-known to be one of the most deliquescent substances in nature. The colors which can be produced by the aid of these three colorless substances, hydrated phosphate of aluminum, hydrated boric acid, and hydrate of potassium are —purple or amethyst, green, blue. Heintz has proved that the color of amethyst is not due to manganese or to titanic acid. Some chemists erroneously attribute the green color of the emerald to a trace of chromic acid; but chrome dissolved in the blow-pipe pearls invariably gives a pinkish hue.—*Ann. de Chem. et de Phys.*, Dec., 1882.

Chinese Telegraphs.—In 1862 Count de Lauture tried to simplify the Chinese language so that it could be used for telegraphing, but he was unable to solve all the difficulties of the problem. In 1866, M. Viguier experimented with autographic telegraphs, and proposed to employ a cipher code, by which the 44,000 Chinese characters could be transmitted by the Morse apparatus. This code was first published in 1870, when a cable was laid between Shanghai and Hong Kong. Every Chinese character is composed of two parts—one is called the *radical* or *key*, the other is phonetic. Every Chinese character can be classed under one of 214 radicals. In his first essay Viguier used three numbers to represent each character—that of the radical, that of the column under the radical and that of its order in the column. This system required the use of numbers varying from three to six ciphers, which rendered the transmission of despatches slow and difficult. By eliminating the characters which are rarely used, and employing those which occur in ordinary correspondence, he was able to simplify his system, so as never to require more than four figures for a single character. To this improved method he added Chase's system of holocryptic ciphers, so that messages can now be sent readily and with perfect secrecy.—*La Lum. Electr.*, Jan. 20, 1883. C.

Forgeable Brass.—A German journal gives this name to an alloy composed of 60 per cent. of copper, 38½ per cent. of zinc, and 1½ per cent. of iron. This alloy has the property of being readily worked

when warm. It can then be employed for constructing various pieces of lock work, which are commonly made of iron, and which, when made of this alloy, would be much less subject to rust.—*Chron. Industr.*, Jan. 14, 1883. C.

Selection of Seeds for Sugar Beets.—According to extensive observations by G. Marek, it is more economical to gather seeds from small than from large beets. There is a saving in land, in cultivation, in harvesting, and in the cost of storage, and the planting in the second year is accomplished much more cheaply and quickly. The seed development from small beets is limited to a small number of stalks, which grow higher and which show less disposition to bend. They produce heavier and brighter seeds, which ripen earlier. In the next planting these seeds produce beets which are rich in sugar and differ in no important point from those which spring from the seeds of larger beets.—*Dingler's Jour.*, Jan. 24, 1883. C.

Examinations of Sugar with Polarized Light.—P. Degener has made comparative experiments with the ordinary apparatus and the "half-shadow" apparatus of Schmidt and Häarsch. He regards the latter as of indisputable value, for persons who are affected with any degree of daltonism and for dark solutions. It may, therefore, be well recommended that manufacturers, who have occasion to investigate the production of sugar from molasses, should add the new apparatus to their other color apparatus.—*Dingler's Jour.*, Jan. 24, 1883.

Selenetropism.—Duchartre was led, by the influence which a light of very feeble intensity exercises upon helotropic movements, to vary the experiments by using moonlight. He sowed seeds of plants which were very sensitive to light, such as *Lens esculenta, Ervum lens, Vicia sativa.* When the plants were a few centimetres in length he put them in a dark place, where he kept them until the night of the experiment. The stalks became slender, long and white; the leaves developed slightly, with a light yellowish tinge. On three successive nights when the sky was exceptionally clear the plants were placed behind a large window with a southern exposure, so that they received the direct light of the moon from 9 P.M. to 3 A.M. From the very beginning of the exposure the stalks began to bend, so as constantly to present their concavity and the terminal leaf bud to the moon, following it in its course.—*Comptes Rendus*, March 5, 1883. C.

Protection of Water Pipes Against Rupture.—Messrs. Buxton and Ross attach a special valve to the extremity of a water-pipe, which can be opened automatically by electricity. They connect with it a thermometer, which is so arranged as to close an electric circuit when the temperature approaches the freezing point. By the influence of the current a wedge is released which allows the valve to fall into place and open the emptying faucet.—*Chron. Industr.*, Jan. 14, 1883.

New Industry in Madrid.—In the neighborhood of the Puerta de Toledo, an establishment has been started for the manufacture of artificial whalebone, from the horns of black cattle and buffaloes. It is said that the factory is provided with all modern improvements, and that its products are already competing successfully with similar articles which are imported from abroad.—*Gaceta Industrial*, June 25, 1883. C.

CORRESPONDENCE.

Committee on Publication of the Journal of the Franklin Institute.

GENTLEMEN:—On page 471 (December, 1883), Prof. L. D'Auria submits a new proposition, *i. e.*, that the attraction is equal on all points of the level of a liquid mass surrounding any solid body, and bases his demonstration on the assumption (not clearly expressed in his letter, but inferable from the conclusion he reaches) that the principle of equal transmission of pressure in hydraulics is such that the pressure is equal on all points having equal normal distance from the surface.

I beg to refer the writer to "Theoretische Maschinenlehre," by Dr. F. Grashof, Leipzig, 1875. Chapter: Hydrostatics. The author defines: *Level-surface* within a fluid in equilibrium denotes any surface of such a character that the resulting force of all attractions is in all points normal to the same. Then he demonstrates that level-surfaces are also surfaces of equal pressure, . . . and that if the external pressure on all points of a free surface of a fluid is uniform, this surface must be a level-surface as defined.

The assumption in the correspondence referred to would therefore depend on the question whether or not all level-surfaces (surfaces of

equal pressure) are equidistant surfaces, for only in this case can the pressure be equal in all points having equal distance below the free surface of the fluid.

It is, however, easy to show that all level-surfaces in any fluid can be equidistant surfaces only if they are perfectly globular, *i. e.*, if the attracting body is a sphere composed of homogeneous spherical layers. Irregularities in the form or density of the attracting body will change the form of the level-surfaces so that they are no more equidistant, and hence the pressure is not uniform on all points having a uniform distance from the free surface of the fluid. This assertion is clearly though not directly expressed in the statement of Dr. Grashof: "Imagine lines drawn through a fluid, which intersect the level-surfaces at right angles, and which may be named lines of greatest change of pressure; then the resultant force of attraction in every point is tangential to the respective line of greatest change of pressure, directed in that sense in which the pressure increases, and the product of this force and the specific mass of the fluid is inversely proportional to the arc-element of the line in question enclosed between two level-surfaces of constant difference of pressure."

The intimation that these lines may be curves shows that the level-surfaces are not necessarily equidistant surfaces, and the final statement shows the attraction to be greatest where the distance between any two level-surfaces is least.

From the foregoing it would appear that the conclusion of your correspondent cannot be correct, being based on an erroneous assumption.

HUGO BILGRAM.

Philadelphia, Dec. 5, 1883.

Book Notices.

GALVANOPLASTIC MANIPULATIONS: A Practical Guide for the Gold and Silver Electroplater and the Galvanoplastic Operator. By William H. Wahl, Ph. D. Philadelphia: Henry Carey Baird & Co., 1883. 8vo, 656 pp.

A practical work on the processes of electro-metallurgy cannot fail to be of interest to the general public as well as to the trade. It has been so long since any connected treatise has been written on this subject, that the general reader has looked in vain for any reliable source

of information concerning the later improvements in galvanoplastic processes. Indeed, so many improvements have been introduced into these processes that the old works are to a great extent worthless, and the need for a more modern treatise has been keenly felt. This want has, we think, been very happily filled by the work of Dr. Wahl, who has produced a book quite up to the present condition of the art.

The author logically begins with a brief statement of the historical facts connected with electro-metallurgy. He divides the general book into three parts, viz., Part I, Thin Metallic Deposits; Part II, Galvanoplastic Operations Proper, or Thick Metallic Deposits; and Part III, Chemical Products and Apparatus used in the Art.

Perhaps one of the most modern features of the work is its description of the applications of the modern dynamo-electric machine to the process of electro-plating. The advantages of these appliances, so fully appreciated by the trade, are here fully and clearly pointed out, and cuts and descriptions given of the principal dynamo-electric plating machines now in the market.

It is eminently proper that nickel-plating, which is an American industry, should receive at the hands of the author the very full and clear treatment he has given it, both from a historical standpoint and in its technical bearings. The discussion of the subject in both of these directions is very clear, and cannot fail to interest the general reader as well as the practical worker.

The process of electrotyping is treated in detail, and full descriptions given of various steps in this important branch of the subject. Illustrations are given of the machinery employed, which includes the modern improvements in this very important art. The process of stereotyping is also fully described. We note essential features of novelty in the chapters on tinning and galvanizing.

The treatment of Part III especially commends itself to the non-technical reader. The difficult subject of the chemical products used in electro-metallurgy are described in language so simple as to enable all to understand it. We note with pleasure the table of chemical names, with their equivalent or ordinary names, which cannot fail to be of value to the workman.

Valuable information of a practical character is given concerning the poisonous character of many of the chemicals employed and the proper antidotes therefor.

The lists of American and British patents connected with the sub-

ject of electro-metallurgy will prove of great value to the general student, affording as it does bibliographical information of a very extended character.

The work closes with an unusually full index. We feel sure that the general arrangement of the work, together with the clear and concise method of its treatment of its topical feature, will commend themselves very favorably to the public. E. J. H.

ELEVENTH BOOK OF SPECIMENS OF PRINTING TYPES, and every Requisite for Typographical Uses and Adornment. Philadelphia: MacKellar, Smiths & Jordan, Nos. 606–614 Sansom street.

THE AMERICAN PRINTER: A Manual of Typography, containing Practical Directions for Managing all Departments a Printing Office, as well as complete Instructions for Apprentices, etc. By Thomas MacKellar, Ph. D. Philadelphia: MacKellar, Smiths & Jordan, 1883.

In the ceaseless current of contributions to our shelves—yearly, monthly, weekly and daily—we have to note an arrival worthy of special mention; it embraces two volumes differing in size and tenor, yet closely allied in their intent and application, namely, a "Specimen of Printing Types" and affiliated Devices, and a text-book of the Art of Printing, styled "The American Printer."

The volume named first is an imposing quarto, bound most substantially and printed on finest paper in the best style of presswork. It is issued from the oldest establishment of the sort in the western hemisphere, and presents the authentic history of the Art in our half of the world.

Devoted, as our Library is, almost exclusively to Mechanics and Chemistry, any case of Fine Art needs a special ticket of admission, but the present case opens the door, and it stands confessed as the happiest union of the Useful and the Beautiful in our keeping.

The other volume is a neat duodecimo, also of faultless workmanship, and is the veritable text-book of the profession, addressing most pertinently at once the apprentice, journeyman and employer, in the language of respectful experience.

These volumes come to us by the courtesy of Messrs. MACKELLAR, SMITHS & JORDAN, of Philadelphia, who are worthy successors of most honored forerunners, among whom stands sturdy James Ronaldson, the first president of the Franklin Institute. H. O.

EXPLOSIVE MATERIALS. By P. E. Berthelot. Translated by Marcus Benjamin. To which is added a Short Historical Sketch of Gunpowder, from the German of Karl Braun. (Van Nostrand's Science Series.) New York: D. Van Nostrand. 12mo, pp. 180. 50 cents.

The first portion of this little book is a resumé of Prof. Berthelot's lectures on explosives before the College de France. After a somewhat detailed enumeration of the many objects to be accomplished by explosive materials, and a classification of these materials as strong and weak, rapid and slow, the force of explosives is considered. M. Berthelot states that this force may be calculated from a knowledge, 1st, of the chemical composition of the explosive; 2d, of the composition of the products of the explosion, to which must be added the quantity of heat given off during the reaction, the volume of the gases formed, and the rapidity with which the reaction takes place. A chapter on the origin of the reactions includes the sensibility of explosives, which is greatest when the explosive material is at the highest initial temperature.

The molecular rapidity of the reaction depends upon a coefficient which varies with the temperature, the pressure, and the relative proportions of the explosive mixture. The influence of the mass of the explosion operated upon is an important factor in the result. While capsules containing 15 mgrs. of fulminate will not explode in mass, if the quantity of fulminate be increased the case is different, and the explosion of one capsule is sufficient to explode not only all others in the same box, but all in the same locality. The rapidity of propagation of explosion varies directly with the pressure, and this brings the author to the consideration of his main point, and his own discovery, the explosive wave which is produced when the pressure produced by the explosion is sufficient to carry the reaction to succeeding particles with the velocity of sound. Explosions by influence are thus explained, but, according to Berthelot, it is not an atmospheric vibration which produces the explosion, but an ether wave. The statement is made that certain experiments demonstrated the propagation of detonation in a mixture of hydrogen and oxygen to take place at the rate of thousands of meters per second.

The Historical Sketch of Gunpowder is quite interesting. The greater part of it is derived from the ancient archives of Augsburg, which city claims the invention of powder by a Jew named Typsiles.

If the documents quoted be trustworthy, Augsburg employed cannon as early as 1372, and was acquainted with their use in 1371.

The book concludes with a very complete and valuable "Bibliography of Works on Explosives," which alone is worth more than the price of the book. W. H. G.

THE MATERIALS OF ENGINEERING, in three parts. Part II, Iron and Steel. By Robert H. Thurston, A. M., C. E., etc. New York: John Wiley & Son, 15 Astor Place, 1883.

The second volume of this work is devoted to the consideration of the manufacture, properties and uses of iron and steel. As introductory to the subject the qualities of metals in comparison with other materials are first discussed, and some account given of the general principles of metallurgy and the materials therein used. Chapter III considers the history of the manufacture of iron; points out its great antiquity—not less than 3,000 or 4,000 B. C.—and shows something of the state of the art among various primative peoples, tracing its development in later years, until the annual product of the iron and steel manufacturers of the United States alone was valued, in 1880, at $300,000,000.

The ores of iron are treated at length in Chapter IV, and their reduction and the manufacture of cast iron there fully considered.

Then follow, in course, descriptions of the various methods of making wrought iron and steel; and the remainder of the work devoted to a consideration of the chemical and physical properties of iron and steel; their strength, the conditions affecting their strength, and finally the subject of specifications is treated, examples given for various kinds of structures, with rules for testing and inspecting.

The work contains a vast amount of information, much of it of a very useful and practical character, and in an available form.

If the matter of the book is open to criticism, it is that certain portions of it are not so thorough or accurate as they appear to be and should be; for example, we note that the illustration which professes to show a steam hammer, such as is used for working puddle-balls, really represents a construction of hammer which is only used in small sizes, and never has been employed in any such work as that described. Again, we note that the cut illustrating the Sellers' Mechanical Puddler, shows a form of machine which it was found necessary to discard years ago, and if we recollect aright, the newer form was exhibited at the Centennial Exhibition.

These matters are not of much moment in themselves, and are only mentioned as a suggestion that the author has not in every case availed himself of the latest information obtainable. The only feature of the work to which we take decided exception is the absurd practice of giving quantities and dimensions in both English and French equivalents.

The book is written in English, and is presumably intended for the use of English speaking engineers and manufacturers; but there is no English speaking community which has adopted the exclusive use of the metric system, and there is not the least probability that there ever will be such a community.

Under these circumstances the constant insertion of parentheses such as those in following sentence: "The anvil is about 6 inches (15·24 centimetres) square, and 6 inches (15·24 centimetres) high," is needlessly annoying to the reader of the book. The present writer is at a loss to conceive of any good result attainable by this practice, which compensates in the slightest degree for the annoyance which it causes the reader, whose pleasure in reading the book is marred every moment by the interjection of these gratuitous translations which destroy the continuity of the sentence and interrupt the course of thought. There is, perhaps, no objection to giving the tabulated results of experiments in "kilograms per square centimetre," as well as in "pounds per square inch," because this enables us readily to compare these results with those of European observers, and if we do not wish to consider them so, it is easy enough to neglect that part of the table; but to translate every quantity that is mentioned in the text into its metric equivalent, results in taking up in many cases from three to five lines out of the thirty-eight, on each page, entirely in this manner. The author, however, is not always consistent, and we notice various places where important quantities are given in English equivalents only.

Franklin Institute.

[*Proceedings of the Stated Meeting, Wednesday, December* 19, 1883.]

HALL OF THE INSTITUTE, Dec. 19, 1883.

The meeting was called to order at the usual hour, with Vice-President, Charles Bullock, in the chair.

There were present 128 members and 19 visitors.

The minutes of the last meeting were approved.

The Actuary submitted the minutes of the Board of Managers, and reported that at the stated meeting held Wednesday, December 12th, 1883, 27 persons had been elected to membership.

The presiding officer announced that he was ready to receive nominations for officers of the Institute to be elected at the annual election in January, 1884. The following members were thereupon placed in nomination, viz.:

For President (to serve one year), William P. Tatham.

" *Vice-President* (to serve three years), Chas. Bullock.

" *Secretary* (to serve one year), William H. Wahl.

" *Treasurer* (to serve one year), Samuel Sartain.

" *Managers* (to serve three years), Washington Jones, Joseph M. Wilson, Coleman, Sellers, C. Chabot, Pliny E. Chase, Dr. Isaac Norris, Theo. D. Rand, A. E. Outerbridge, Jr.

For Managers (to serve for two years), Hugo Bilgram, Charles J. Shain.

For Auditor (to serve three years), Lewis S. Ware.

" *Trustee in Pennsylvania Museum and School of Industrial Art* (to serve for one year), William H. Wahl.

The Special Committee on "Ordinance for the Examination of Steam Engineers," presented majority and minority reports, which were freely discussed by Messrs. Washington Jones, Coleman Sellers, Jr., William Helme, N. P. Williames, Wm. B. LeVan and J. W. Nystrom. On motion of Mr. LeVan, seconded by Mr. W. B. Cooper, the consideration of the reports was postponed until the next stated meeting.

On Mr. Nystrom's motion, seconded by Mr. LeVan, it was ordered that the reports be printed, and copies thereof placed at the service of members.

The Secretary's Report embraced a *resumé* of the progress of the work on the Electrical Exhibition; a description of Barnard's Adjustable Telephone Receiver, the principal feature of which is a double receiver, one for each ear, and so arranged upon a handle as to permit it to be readily fitted against the ears of heads of all sizes. The device frees the user of the telephone from the annoyance and distraction arising from local noises. Clark's portable Electric Gas-Lighter, shown on behalf of J. Chester Wilson, of Philadelphia, and consisting of a combination of an open circuit battery, and a Ruhmkorff coil